CHAPTER 2

PAVEMENT DESIGN

200.00 INTRODUCTION

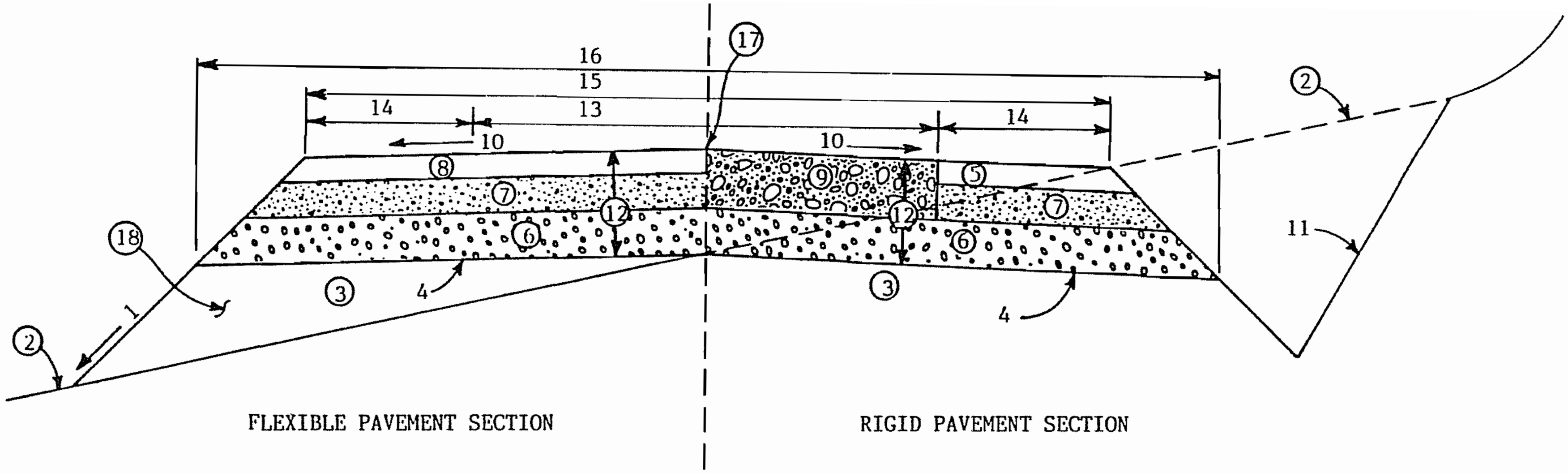
The remaining chapters deal with the procedures used by the Arizona Department of Transportation for the different facets of materials design of new pavements and rehabilitation of existing pavements; both rigid and flexible. This chapter will provide a guide for determining pavement structures similar to the ones shown in Figure 200.00-1. The design procedures provided will include the determination of the total pavement thickness as well as the thickness and structural value of each of the individual pavement components, the determination of alternate designs and the selection of optimum designs based on costs, conservation of materials or some other aspect will also be discussed.

Regardless of what type of design is involved (new construction, rehabilitation, widening, etc.) the collection and analysis of the information available on a project is the foundation for all that follows in the materials design process. The designer must integrate this information into the Materials Design Package (Materials Design Memo, Design Summary and Preliminary Pavement Structure Cost Estimate) that will provide the necessary documentation and communication of this design process. The information provided in Figure 200.00-2 gives an idea of some of the data required for the design analysis of different types of projects.

In the subsections that follow, this process will be discussed in detail.

200.01 PROJECT DETERMINATION

Whether it be from the scope of work, project assessment, design concept report or from the original project request form, the determination of a project's location and intent is the starting point for the design process. With this information the preliminary sampling, testing and data requirements for the project can usually be determined.



1 – FILL SLOPE
2 – NATURAL GROUND LINE
3 – SUBGRADE
4 – FINISHED SUBGRADE ELEVATION
5 – SHOULDER SURFACING
6 – SUBBASE COURSE
7 – BASE COURSE
8 – SURFACE COURSE
9 – PAVEMENT SLAB
10 – CROSS SLOPE
11 – CUTSLOPE
12 – PAVEMENT STRUCTURE
13 – TRAVEL LANES
14 – SHOULDER
15 – ROADWAY SURFACE
16 – ROADBED
17 – FINISHED ℄ GRADE
18 – FILL/EMBANKMENT

TYPICAL SECTION FOR RIGID OR FLEXIBLE PAVEMENT STRUCTURE

FIGURE 200.00-1

DATA REQUIRED FOR DIFFERENT TYPES OF CONSTRUCTION PROJECTS

DATA REQUIRED	NEW CONSTRUCTION	RECONSTRUCTION	WIDENING	AC PAVEMENT REHABILATATION	PCCP REHABILATATION	SURFACE TREATMENTS
SCOPE OF WORK	H	H	H	H	H	M
DESIGN CONCEPT REPORT	H	H	H	M	M	L
EXISTING AS-BUILT INFORMATION	N/A	H	H	H	H	H
ROUGHNESS, SKID, CRACKING (TYPE AND %)	N/A	L	M	H	H	H
DEFLECTION TESTING	N/A	L	H	H	M	L
FIELD INVESTIGATION	H	H	H	H	H	H
EXISTING PAVEMENT CONDITION	N/A	L	M	H	H	H
ENVIRONMENT & DRAINAGE	H	H	H	M	M	L
SUBGRADE SAMPLING & TESTING	H	H	M	L	L	N/A
MATERIAL SOURCES	H	H	H	M	M	L
TRAFFIC DATA (ADT AND ADL)	H	H	H	H	M	L

LEVEL OF NEED H = HIGH, M = MODERATE, L = LOW

FIGURE 200.00-2

200.02 DATA COLLECTION

For projects on the State Highway System the existing information is obtained from the pavement management history file which includes project numbers, date of construction, layer types and history sorted by route and milepost. For projects involving existing pavements on the State Highway System the data obtained by the annual surveys of the Pavement Management Unit is available. This survey information includes ride roughness, percent cracking, patching, flushing, skid resistance and rutting (interstate only) of the existing pavement. Additionally, although not done annually, Dynaflect or Falling Weight Deflectometer test results may also be available. Additional information is available at Engineering Records and includes, but is not limited to the following:

A. As-built Plans

B. Design and Construction Files

C. Location Surveys

D. Materials Files

E. Drainage Reports

For those projects not on the State Highway System, the information is usually available from the responsible agency.

200.03 FIELD INVESTIGATION

On new construction, reconstruction and widening projects the materials design survey should be held in conjunction with the geotechnical field review.

On rehabilitation projects a field survey should take place shortly after the existing information available has been analyzed. The importance of a field survey on rehabilitation projects cannot be over emphasized, for the information obtained concerning the existing pavement condition and apparent distress is necessary for reliable rehabilitation strategy selection. The following is a partial check list for items that should be investigated during the field survey for pavement rehabilitation projects:

A. Existing Pavement Condition

1. Cracking (type and percentage)
2. Surface Course (type and condition)
3. Maintenance (type and percentage)

4. Shoulder or Distress Lane Condition
5. Change in condition, distress, or surface type

B. Related Items

1. Drainage
2. Terrain
3. Roadway Grade and Section (cross slope)
4. Soils

C. General

1. Project Limits (Verification and Reasoning)
2. Bridge Structures (Clearance and Surface Type)
3. Ramp and Crossroad Pavement Condition
4. Ride Quality
5. Embankment Slopes and Guard Rail Height
6. Curb Heights and Overlay Buildup in Gutter

200.04 GEOTECHNICAL INFORMATION

A. Centerline Working Profile

During the centerline investigation of new construction projects, data is recorded that should be analyzed and used in the design process.

1. Test Holes

The location and depth of the holes are shown, and should be studied to determine if the roadway cuts are reasonably represented by samples.

2. Excavation Factors

The excavation factors for each cut are shown on the profile.

3. Cut Slopes

The recommended cut slopes are shown on the profile.

4. Ground Compaction

The amount of ground compaction to be compensated for is shown on the profile.

5. Miscellaneous Notes

Unusual conditions encountered during the investigation are noted on the profile. Examples include underground springs, slides or potential slides, piping, unusual erosion, or other phenomena. These should be studied and recommendations made in the memo.

B. Logs

The log of the test hole indicates the Field Supervisor's desciption of the material. It also indicates if the material was removed with or without blasting and indicates depths of various stratas of different materials. Also indicated is the material type at the bottom of the test hole.

C. Special Reports

If there were any unusual conditions found during the materials investigation that required special investigation and study, the report of these investigations and studies should be analyzed and recommended measures included in the design process.

D. Pit Sketches and Pit Field Reports

Pit sketches and Pit Field Reports should be analyzed to determine the following information to be incorporated in the Materials Design Memorandum on the pit data sheet.

1. Pit Sketches

Pit sketches will provide the following data:

a. Location

The pit sketch (Figure 104.06-4 and 104.06-5) will give the location of the pit usually in relation to a Station on the adjacent highway. It should also show the Section, Township and Range. The memo need only include the reference to the Station. For example: pit ADOT Serial No. 8491, located approximately 1.5 miles from Station 1807 (US 89) on a ridge.

b. Quantity

The quantity of available material may be calculated by multiplying the area shown on the pit sketch by the average depth of the usable material. It should be expressed in cubic yards. Because the area of the pit is usually irregular, the area may best be determined by use of planimeter. The calculation of quantity available should be conservative, assuming there will be a certain amount of waste and some areas that may not be workable. The shrink or swell factor should be applied in determining the final quantity.

2. Pit Report

The Geotechnical Analysis will include the following information:

a. Detailed description of the type of pit and nature of material within.

b. Haul road requirements.

c. Description of Pit Environment.

E. Geotechnical Report

The geotechnical report is used to summarize and document the geotechnical information obtained on a project. This information is used during the design process and for completing the geotechnical portion of the Materials Design Memo.

200.05 TRAFFIC ANALYSIS

The calculation of projected traffic is determined from data furnished by either the Transportation Planning or the Local Government Coordination Group. Generally, the Local Government Coordination Group provides data for all urban areas, except Tucson and Maricopa County for which this data is furnished by Pima Association of Governments (PAG) and Maricopa Association of Governments (MAG). Data for all other areas is provided by Transportation Planning.

The calculation of the estimated cumulative number of 18-Kip equivalent single axle loads (ESAL) for a design (or performance) period is performed by the Materials Section for all State highways. The calculations are performed at least once every year and computer reports distributed to those involved with the pavement design process.

For more details concerning traffic data procedures and analysis see Appendix A.

200.06 PRELIMINARY PLANS

The preliminary plans show the geometrics of the major roadway section. In addition to the major roadway, designs should be provided for all ramps, crossroads, frontage roads, access roads, and roadside rest areas. Provision should also be made, where applicable for detours, turnouts, median paving and other incidental work called for on the plans.

201.00 GENERAL PAVEMENT DESIGN CONSIDERATIONS - NEW CONSTRUCTION

The performance of a pavement structure is directly related to the properties and condition of the roadbed soils. The design procedures in this manual are based on the assumption that most soils can be adequately represented for pavement design purposes by mean values of the soil's resilient modulus (M_R), for flexible pavements, or the modulus of subgrade reaction (k), for rigid pavements. However, certain soils such as those that are excessively expansive, resilient, frost susceptible, or highly organic require that additional steps be taken to provide for adequate pavement performance.

Since the borrow may provide the control for the design of the pavement structure, the test data for designated borrow sources should be carefully studied. The quality of the material will be indicated by the R-value with the lowest number, indicating the poorest material. If the materials source is fairly uniform the mean R-value of the material should be used for the control. However, if most of the source is uniformly high in quality with perhaps only a few test holes with a low R-value, the source should be studied to see if the unfavorable materials may be isolated and eliminated from the pit area so the mean R-value of the higher quality material may be used for the design and construction of the project.

Where there is more than one borrow source on a project and there is considerable difference in the R-value of the various sources, a cost study should be made to determine the feasibility of hauling the higher quality material longer distances versus using the lower quality materials which will require additional pavement structure. The results of these studies will help to determine the final selection of the borrow sources.

Many projects will not have designated borrow sources and it will be the contractors responsibility to locate needed material. The pavement designer will need to anticipate the likely R-values of borrow material for the project and design the project accordingly. The anticipated mean R-value and associated standard deviation will need to be specified for inclusion in the project specifications. The contractor will be required to provide borrow sources, and test results demonstrating that his sources meet or exceed the mean and standard deviation requirements.

A. Subgrade Tabulations

The subgrade tabulations contain essentially the same test information as the borrow tabulations with the location of the test holes identified in relation to a Station on the project.

The subgrade tabulations should be studied carefully together with the preliminary construction profile to determine the design controls for each pavement structure. Only that material which is expected to be placed within the top 3 feet of finished subgrade elevation should be included in the statistical analysis of R-values. At the time the pavement structure is designed, there is usually no earthwork computation available to indicate this, therefore judgement should be exercised in determining the length of each pavement design section. This may be subject to adjustment when earthwork quantities are available.

Isolated small areas of poor quality material may be omitted in the design by specifying that the material be removed to a depth of 3 feet below finished subgrade elevation and replaced with acceptable material. The removed material may be placed in embankment sections a minimum of 3 feet below finished subgrade elevation.

In the analysis of the subgrade, careful consideration should be given to areas where test results indicate conditions that might generate problems in construction and performance of the pavement structure. Such conditions may include, but not necessarily be limited to, low R-values, high plasticity, high percentage passing the #200 sieve, expansive clays, high moisture content, frost susceptibility, settlement, collapsible soil, etc. Each such condition should be examined and engineering judgement applied to determine what should be recommended in the pavement design memo to preclude such problems.

Other problems related to roadbed soils are the nonuniform support that results from wide variations in soil type or condition; the additional densification under traffic of soils that are not adequately compacted during construction; and construction difficulties, particularly those associated with compaction of cohesionless sands and wet, highly plastic clays.

With these problems in mind, the following adverse conditions listed below should be considered in design. If necessary, the Soils Engineer should be consulted to assist in identifying the problem and recommending a solution. It should be noted that the solutions given for each condition are not the only answer and each problem area should be studied on an individual basis. Appropriate statements of recognition of the problems and solutions should be included in the design memo.

1. Soils that are excessively expansive should receive special consideration. Generally, expansive soils have high plasticity indices, high percentage passing the #200 sieve, low "R"-values, and are A-6 and A-7 soils according

to the AASHTO Soil Classification System. One solution may be to cover these soils with a sufficient depth of selected material to overcome the detrimental effects of expansion. Expansion may often be reduced by tight control of the compaction water content. In some cases, it may be more economical to treat expansive soils by stabilizing with suitable admixture, such as lime or cement, to over excavate and replace the material or to encase a substantial thickness in a waterproof membrane to stabilize the water content. Also, widening and deepening the cut ditches and providing the shoulder slopes with a membrane, may help to stabilize the roadway section.

2. Low shear strength soils generally are those soils that have low "R"-values, (15 or less). Although these soils can be compensated for by increasing the structural thickness, it may be more economical in the long term to treat them with a suitable admixture such as lime or cement. In some cases geosynthetics may be appropriate. Additionally, the shear strength may be improved by blending with a granular soil. If the low shear strength soil is in limited areas, it may be most economically treated by over-excavating and replacing with a selected material.

3. In areas with a freezing index, the pavement design should include an analysis of the effects of frost in addition to the analysis for traffic loadings. A complete explanation of the design procedures for frost conditions is contained in Appendix B.

4. Problems with highly organic soils are related to their extremely compressible nature, and are accentuated when deposits are extremely nonuniform in properties or depth. Local deposits, or those of relatively shallow depth, may be most economically excavated and replaced with suitable selected material. Problems associated with deeper and more extensive deposits may be alleviated by placing surcharge embankments for preconsolidation, sometimes with special provisions for rapid removal of water to hasten consolidation.

5. Special provisions for unusually variable soil types and conditions may include: scarifying and recompacting; treatment of an upper layer of roadbed soils with a suitable admixture; using appreciable depths of more suitable roadbed soils; overexcavation of cut sections, and placing a uniform layer of selected material in both cut and fill areas; adjustment in the thickness of subbase at transitions from one soil type to another, particularly when the transition is from cut to fill section, or the use of geosynthetics.

6. Although the design procedure is based on the assumption that provisions will be made for surface and subsurface drainage, unusual situations may require that special attention be given to design and construction of drainage systems. Drainage is particularly important where continual flows of water are encountered (i.e., springs or seeps); where detrimental frost conditions are present; or where soils are particularly susceptible to expansion or loss of strength with increase in water content. Special subsurface drainage may include provision of additional layers of permeable material beneath the pavement for interception and collection of water, and pipe drains for collection and transmission of water. Special surface drainage may require such facilities as dikes, paved ditches, and catch-basins. For additional information on subsurface drainage see FHWA Reports RD-73-14, TS-80-224, and TS-86-208.

7. Certain roadbed soils pose difficult problems during construction. These are primarily the cohesionless soils, which are readily displaced under equipment used to construct the pavement; and wet clay soils, which cannot be compacted at high water contents because of displacement under rolling equipment and require long periods of time to dry to a suitable water content. Measures that may be applied to alleviate such construction problems include; blending with other soils or adding suitable admixtures to sands to provide cohesion, or to clays to hasten drying or increasing shear strength; covering with a layer of more suitable selected material to act as a working platform for construction of the pavement, or use of a geosynthetic to provide additional stability.

After a systematic evaluation of results of the soils investigation, the process of designing pavement structures consists of applying these results to a rational pavement structure design procedure. The design procedures will yield the approximate thicknesses of subbase, base course, and surface course. The following sections will describe those procedures employed by the Arizona Department of Transportation for the designing of pavement structures for flexible pavements, rigid pavements, asphaltic concrete overlays and other pavement rehabilitation strategies.

202.00 PAVEMENT DESIGN

202.01 - GENERAL INFORMATION

The Arizona Department of Transportation is adopting the 1986 AASHTO Guide for Design of Pavement Structures for new construction of both flexible and rigid pavements. This AASHTO publication significantly changes pavement design and the reader is advised to obtain a copy of it for additional background material. Because of the numerous changes embodied in the AASHTO Guide, it is not possible in this manual to cover all design aspects for both flexible and rigid pavements. In this respect the Materials Section Preliminary Engineering and Design Manual presents how the AASHTO Guide will be applied for the Arizona Department of Transportation (ADOT). Thus, much of what is presented here will be ADOT's modifications and conventions necessary to obtain designs that will perform as well or better than the tentative AASHTO Guide and with greater reliability. In addition criteria are presented to facilitate the use of new materials and concepts consistent with construction control practices and pavement management policies. In general the designer should have a greater opportunity to try different designs, with the goal of obtaining the most cost effective design. Many of the following concepts can be applied to both flexible and rigid pavements, however, in keeping with the AASHTO Guide flexible pavements will be discussed first.

202.02 - FLEXIBLE PAVEMENT DESIGN

A. The basic design equation used for flexible pavements is as follows:

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left[\dfrac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \dfrac{1094}{(SN + 1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

Where

W_{18} = predicted number of 18-kip equivalent single axle load applications (Flexible)

Z_R = standard normal deviate,

S_o = combined standard error of the traffic prediction and performance prediction,

ΔPSI = $P_0 - P_t$

P_0 = initial design serviceability index

P_t = design terminal serviceability index,

M_R = resilient modulus (psi).

SN is equal to the structural number indicative of the total pavement section required:

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

Where

a_1 = i^{th} layer coefficient,

D_1 = i^{th} layer thickness (inches) and

m_2 = i^{th} layer drainage coefficient.

B. W_{18} Determination

The calculation of the estimated cumulative number of 18-Kip equivalent single axle loads (ESAL) for a design (or performance) period is performed by the Pavement Management Branch of the Materials Section for all State highways. The calculations are performed at least once each year and computer reports distributed to those involved with the pavement design process.

The calculation of the estimated ESAL is based on:

1) traffic volume (ADT) (Average Daily Traffic plus growth factor)
2) vehicle equivalencies (Growth factor and tire pressure)
3) vehicle classification

All of these traffic data are obtained from the Transportation Planning Division for state highway project design. Local Government groups will furnish the traffic information for their projects. Traffic estimates and calculations can be very difficult to obtain for ramps, crossroads and frontage roads. Ramps and crossroads should be estimated to have traffic loads of at least five percent of the mainline traffic loading. Likewise, frontage roads should be estimated to be at least one percent of the mainline traffic loading. If actual traffic measurements give larger calculated traffic values, these actual measures should be used.

A detailed explanation of the assumptions, equations and calculations for the determination of the traffic loading used for pavement design is given in Appendix A.

C. Z_R Determination

Standard normal deviate is a measure of how likely a pavement is to fail within the design period. If Z_R of -2.327 is selected there is only one chance in a hundred that the pavement will fail during its design period. Conversely, there is a 99 percent chance a pavement will not fail within the design period, which can be called the level of reliability. Table 202.02-1 gives the level of reliability in percent, as well as the Z_R values that should be used for design.

D. S_o - In keeping with the AASHTO Guide a combined standard error of 0.45 for flexible pavements.

E. ΔPSI - Over a 20 year design period there will be a change in present serviceability index. Arizona's pavement management data base indicates that this change is a function of highway type as shown below in Table 202.02-2.

F. M_R - Resilient Modulus of Subgrade

For flexible pavement design, the primary soil strength measure used by ADOT is the Resilient Modulus, M_R, as determined thru R-Value analysis. Due to the much greater amount of time and expense of the R-value sampling and testing process, a method of estimating R-values and hence, M_R values, from other more common tests has been developed.

TABLE 202.02-1

LEVEL OF RELIABILITY (PERCENT)

Divided Highways, Freeways and Interstates	99%
Non-Divided, Non-Interstate Highways, 10,000+ ADT	95%
2,001 - 10,000 ADT	90%
501 - 2,000 ADT	85%
≤500 ADT	75%

Z_R values for each level of reliability:

75%	=	-0.674
80%	=	-0.841
85%	=	-1.037
90%	=	-1.282
95%	=	-1.645
99%	=	-2.327

TABLE 202.02-2

SERVICEABILITY INDEX

	P_o	P_t	△PSI Change in PSI
Divided Highways, Freeways & Interstates	4.2	3.0	1.2
Non-Divided, Non-Interstates Highways, 10,000+ ADT	4.2	2.8	1.4
2,001-10,000 ADT	4.1	2.6	1.5
501-2,000 ADT	4.1	2.6	1.5
≤ 500 ADT	4.0	2.4	1.6

Extensive regression and correlation analyses have been performed using the gradation and the Plasticity Index, Liquid Limit and Sand Equivalent test as indicators and predictors of R-value. Of the many candidate equations and relationships considered, a family of curves was finally chosen as the best workable relationship between gradation and Plasticity Index. The general form of the equation is:

$$\log \text{R-Value at 300 psi} = 2.0-0.006(\text{Pass 200})-0.017(\text{PI})$$

A soil strength correlation table has been constructed to simplify the solution to the mathematical relationships developed between R-value, Plasticity Index and Percent Pass #200 sieve (Table 202.02-3) For example, given a PI of 12 and a percentage pass the #200 sieve of 39, Table 202.02-3 produces an R-value of 36.

For design purposes, the design R-Value used should be determined from the correlated R-value, R_c, results (from PI and 200's) as well as from actual R-value, R_t, tests (AASHTO T 190).

All soil samples delivered to the testing laboratory should be accompanied by a field log and work instructions initialed by the requestor. All samples will be tested for Gradation (coarse screen and fine screen/elutriation) and plasticity index. Additionally, tests such as densities, pH and resistivities etc., will be performed as instructed, with the exception of R-value tests. Prior to performing R-value tests, all soil sample results will be analyzed to determine the samples on which to run actual R-values.

The correlated R-values will be analyzed and representative samples will be selected from those that were initially sampled for R-values. Those selected samples will actually be tested for R-values. It is recommended that if the lowest correlated R-value is greater than 65, and the designer determines that an R-value higher than this will not significantly change his pavement design, that it may be advisable not to perform any actual R-values and use a representative correlated R-value instead.

This process of eliminating R-value tests is a recommendation to minimize testing and expedite the design process. The designer may opt to have all R-value tests run.

After R-value testing is completed, all test results will be relayed to the designer for further evaluation. If after analysis, the test results suit the designers needs, no further sampling or testing will be required. If not, the designer may request additional sampling and testing.

TABLE 202.02-3

BODY OF TABLE IS R-VALUE AT 300 psi EXUDATION PRESSURE

PERCENT PASSING #200 SIEVE

PI	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96
0	100	96	92	88	85	81	78	75	72	69	66	63	61	58	56	54	52	49	47	45	44	42	40	39	37	35	34	33	31	30	29	28	27
1	96	92	89	85	81	78	75	72	69	66	64	61	58	56	54	52	50	48	46	44	42	40	39	37	36	34	33	31	30	29	28	27	26
2	92	89	85	82	78	75	72	69	66	64	61	59	56	54	52	50	48	46	44	42	40	39	37	36	34	33	31	30	29	28	27	26	25
3	89	85	82	79	75	72	69	67	64	61	59	56	54	52	50	48	46	44	42	40	39	37	36	34	33	32	30	29	28	27	26	25	24
4	86	82	79	76	72	70	67	64	61	59	56	54	52	50	48	46	44	42	41	39	37	36	34	33	32	30	29	28	27	26	25	24	23
5	82	79	76	73	70	67	64	62	59	57	54	52	50	48	46	44	42	41	39	37	36	34	33	32	30	29	28	27	26	25	24	23	22
6	79	76	73	70	67	64	62	59	57	54	52	50	48	46	44	42	41	39	37	36	35	33	32	30	29	28	27	26	25	24	23	22	21
7	76	73	70	67	64	62	59	57	55	52	50	48	46	44	43	41	39	38	36	35	33	32	31	29	28	27	26	25	24	23	22	21	20
8	73	70	67	65	62	59	57	55	52	50	48	46	44	43	41	39	38	36	35	33	32	31	29	28	27	26	25	24	23	22	21	20	19
9	70	67	65	62	60	57	55	53	50	48	46	45	43	41	39	38	36	35	33	32	31	29	28	27	26	25	24	23	22	21	20	19	19
10	68	65	62	60	57	55	53	51	49	47	45	43	41	39	38	36	35	33	32	31	30	28	27	26	25	24	23	22	21	20	19	19	18
11	65	62	60	57	55	53	51	49	47	45	43	41	40	38	36	35	33	32	31	30	28	27	26	25	24	23	22	21	20	20	19	18	17
12	63	60	58	55	53	51	49	47	45	43	41	40	38	36	35	34	32	31	30	28	27	26	25	24	23	22	21	20	20	19	18	17	17
13	60	58	55	53	51	49	47	45	43	41	40	38	37	35	34	32	31	30	29	27	26	25	24	23	22	21	20	20	19	18	17	17	16
14	58	55	53	51	49	47	45	43	41	40	38	37	35	34	32	31	30	29	27	26	25	24	23	22	21	21	20	19	18	17	17	16	15
15	56	53	51	49	47	45	43	42	40	38	37	35	34	32	31	30	29	27	26	25	24	23	22	21	21	20	19	18	17	17	16	15	15
16	53	51	49	47	45	43	42	40	38	37	35	34	33	31	30	29	28	26	25	24	23	22	21	21	20	19	18	17	17	16	15	15	14
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18	49	47	45	44	42	40	39	37	35	34	33	31	30	29	28	27	25	24	23	22	22	21	20	19	18	18	17	16	15	15	14	14	13
19	48	46	44	42	40	39	37	36	34	33	31	30	29	28	27	26	24	23	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13
20	46	44	42	40	39	37	36	34	33	31	30	29	28	27	26	25	24	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12
21	44	42	40	39	37	36	34	33	32	30	29	28	27	26	25	24	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12
22	42	41	39	37	36	34	33	32	30	29	28	27	26	25	24	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11
23	41	39	37	36	34	33	32	30	29	28	27	26	25	24	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11	11
24	39	37	36	35	33	32	30	29	28	27	26	25	24	23	22	21	20	19	19	18	17	16	16	15	14	14	13	13	12	12	11	11	10
25	38	36	35	33	32	31	29	28	27	26	25	24	23	22	21	20	19	19	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10
26	36	35	33	32	31	29	28	27	26	25	24	23	22	21	20	19	19	18	17	16	16	15	15	14	13	13	12	12	11	11	10	10	10
27	35	33	32	31	29	28	27	26	25	24	23	22	21	20	19	19	18	17	16	16	15	15	14	13	13	12	12	11	11	10	10	10	9
28	33	32	31	30	28	27	26	25	24	23	22	21	20	19	19	18	17	17	16	15	15	14	13	13	12	12	11	11	10	10	10	9	9
29	32	31	30	28	27	26	25	24	23	22	21	20	20	19	18	17	17	16	15	15	14	13	13	12	12	11	11	10	10	10	9	9	9
30	31	30	28	27	26	25	24	23	22	21	20	20	19	18	17	17	16	15	15	14	13	13	12	12	11	11	11	10	10	9	9	9	8
31	30	29	27	26	25	24	23	22	21	20	20	19	18	17	17	16	15	15	14	14	13	12	12	11	11	11	10	10	9	9	9	8	8
32	29	27	26	25	24	23	22	21	21	20	19	18	17	17	16	15	15	14	14	13	12	12	11	11	11	10	10	9	9	9	8	8	8
33	27	26	25	24	23	22	21	21	20	19	18	17	17	16	15	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7
34	26	25	24	23	22	21	21	20	19	18	17	17	16	15	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7
35	25	24	23	22	22	21	20	19	18	17	17	16	15	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7
36	24	23	22	22	21	20	19	18	18	17	16	15	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	6
37	23	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	7	6
38	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	7	6	6
39	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	7	6	6	6
40	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10	10	9	9	8	8	8	7	7	7	7	6	6	6	6
42	19	19	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10	10	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5
44	18	17	16	16	15	15	14	13	13	12	12	11	11	10	10	10	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5
46	17	16	15	15	14	13	13	12	12	11	11	10	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4
48	15	15	14	13	13	12	12	11	11	11	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4
50	14	14	13	12	12	11	11	11	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4
52	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3
54	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3
56	11	11	10	10	9	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3
58	10	10	10	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3
60	10	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3
62	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2
64	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2
66	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2
68	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2
70	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2
72	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2
74	6	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1
76	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1

G. Mean R-Value Determination

1. The following items should be considered in the selection of the Mean R-value for design.

a. Determine the soil types that will compose the finished subgrade.

b. Will the subgrade be composed of in-place material, roadway excavation or borrow?

c. If roadway excavation controls, estimate to what limits the material will be placed.

d. Different types (AASHTO SOIL CLASSIFICATION) of material in the cuts?

e. The approximate volume each material type represents.

f. The location within the cut of each material type (at grade, horizontal stratum, etc.).

g. Length and depth of fill areas adjacent to the cut.

h. Feasibility of stabilizing (lime and cement) soils with a low R-value (R less then 15). Such stabilized layers will be characterized by a structural coefficient based upon strength.

i. Feasibility of controlling placement of excavation.

(1) Specify station limits for hauling excavation.

(2) Specify material not used within 3 feet of finished subgrade elevation.

j. Feasibility of using Geosynthetics. For purposes of the design the mean subgrade R-value should be increased by 10 when a geosynthetic is used.

k. Possibility of using material in a place where the soil strength is not critical (e.g., dike construction, slope plating). Wasting poor material should also be considered.

l. Over excavation (especially at grade-in and grade-out points) and replacement with a better material.

m. Stripping of overburden and placement in lower level of fills.

2. Determine the Mean and Construction Control R-values by analysis of the test data for the soil types(s) that will compose the finished subgrade. Test results from soils that will not be part of the 3 feet immediately below finished subgrade elevation should not be included in this analysis. If borrow will be used, the test results from the borrow will need to be either incorporated into the analysis or analysed separately. Both correlated (Rc) and actual (Ra) R-values should be incorporated into the analysis. The means of the Rc and Ra values are determined separately and combined thru the formula to arrive at the mean R-value.

$$R_{mean} = \frac{N_t R_t \sigma_c^2 + N_c R_c \sigma_t^2}{N_t \sigma_c^2 + N_c \sigma_t^2}$$

Where N_t = number of actual R-values
N_c = number of correlated R-values (from PI & 200)
R_t = mean of the actual R-values
R_c = mean of the correlated R-values
σt = standard deviation of the actual R-values
σc = standard deviation of the correlated R-values

The standard deviation of the Rc values that were used in determining the mean R-value should also be used in determining the construction control R-value.

H. Resilient Modulus Determination

Once the mean R-value has been determined, it should be converted to a resilient modulus value, M_r, thru the equation:

$$M_R = \frac{1815 + 225*(R_{mean}) + 2.40*(R_{mean})^2}{0.6(SVF)^{0.6}}$$

Where SVF is the seasonal variation factor from Figure 202.02-1. For further clarification Table 202.02-4 shows SVF values for each city shown on the map.

This M_R value is used as the input value for the AASHTO Flexible Pavement design equation. The M_R value is also used to determine the modulus of subgrade reaction (k) for input in the rigid pavement design equation. Figure 202.02-2 graphically presents the relationship between M_R, SVF and mean R-value. Generally, the design M_R value for subgrade materials should not exceed 26,000 psi.

FIGURE 202.02-1

SEASONAL VARIATION FACTOR

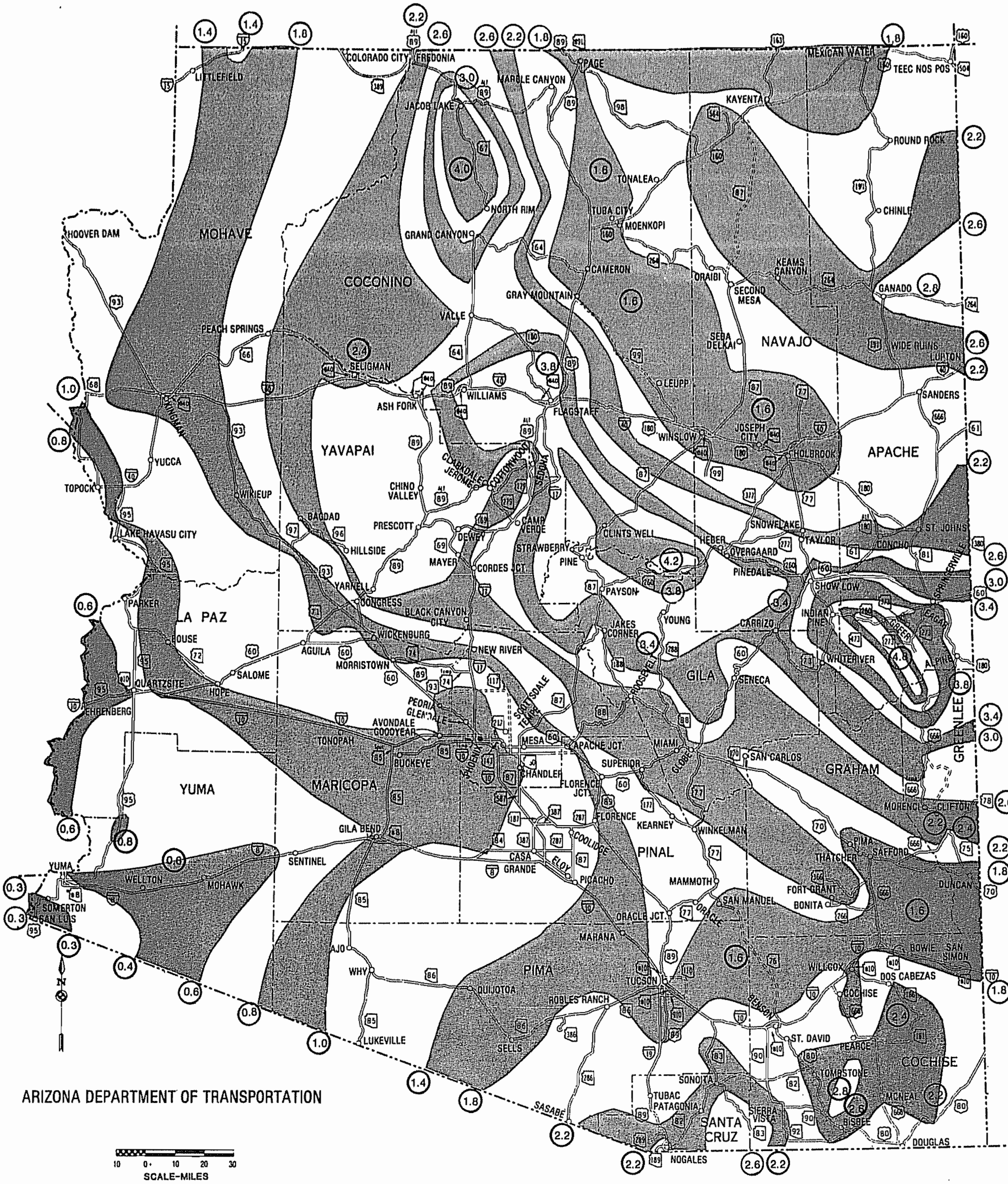


TABLE 202.02-4

LOCATION	SEASONAL VARIATION FACTOR
Aguila	1.1
Ajo	1.2
Alpine	3.8
Apache Junction	1.2
Ash Fork	2.7
Avondale	1.0
Bagdad	2.3
Benson	1.9
Bisbee	2.6
Black Canyon City	2.5
Bonita	2.1
Bouse	1.0
Bowie	1.7
Buckeye	0.9
Cameron	1.5
Camp Verde	2.1
Carrizo	3.3
Casa Grande	1.0
Chandler	1.0
Chinle	2.1
Chino Valley	2.7
Clarkdale	2.3
Clifton	2.6
Clints Well	4.1
Colorado City	1.9
Concho	2.2
Congress	1.7
Coolidge	1.0
Cordes Junction	2.6
Cottonwood	2.2
Dewey	2.7
Dos Cabezas	2.4
Douglas	1.9
Duncan	1.7
Eager	3.7
Ehrenberg	0.5
Eloy	1.1
Flagstaff	3.5
Florence	1.3
Florence Junction	1.9

TABLE 202.02-4 (Cont'd.)

LOCATION	SEASONAL VARIATION FACTOR
Fort Grant	2.1
Fredonia	1.9
Ganado	2.6
Gila Bend	0.8
Glendale	1.0
Globe	2.6
Goodyear	1.0
Grand Canyon	2.6
Gray Mountain	2.0
Greer	4.2
Heber	3.1
Hillside	2.6
Holbrook	1.7
Hoover Dam	1.0
Hope	1.0
Indian Pine	4.1
Jacob Lake	3.1
Jakes Corner	2.4
Jerome	2.6
Joseph City	1.7
Kayenta	1.8
Keams Canyon	2.4
Kearney	2.1
Kingman	1.7
Lake Havasu City	0.5
Leupp	1.5
Littlefield	1.2
Lukeville	1.2
Lupton	2.2
Mammoth	2.1
Marana	1.6
Marble Canyon	1.7
Mayer	2.7
McNeal	1.9
Mesa	1.0
Mexican Water	1.8
Miami	2.8
Moenkopi	1.7
Mohawk	0.5
Morenci	2.6
Morristown	1.5
New River	1.5
Nogales	2.3

TABLE 202.02-4 (Cont'd.)

LOCATION	SEASONAL VARIATION FACTOR
North Rim	4.0
Oracle	2.3
Oracle Junction	2.1
Oraibi	2.0
Overgaard	3.3
Page	1.5
Parker	0.5
Patagonia	2.5
Payson	3.5
Peach Springs	1.8
Pearce	1.9
Peoria	1.0
Phoenix	1.0
Picacho	1.3
Pima	1.6
Pine	3.9
Pinedale	3.1
Prescott	3.2
Quartzsite	0.6
Quijotoa	1.6
Robles Ranch	1.8
Roosevelt	2.3
Round Rock	1.9
Safford	1.6
Salome	1.0
San Carlos	2.0
San Luis	0.3
San Manuel	1.9
San Simon	1.6
Sanders	2.0
Sasabe	2.2
Scottsdale	1.0
Seba Delkai	1.8
Second Mesa	1.8
Sedona	2.4
Seligman	2.7
Sells	1.6
Seneca	3.4
Sentinel	0.6
Show Low	3.4
Sierra Vista	2.0
Snowflake	2.5
Somerton	0.3

TABLE 202.02-4 (Cont'd.)

LOCATION	SEASONAL VARIATION FACTOR
Sonoita	2.1
Springerville	3.7
Strawberry	4.1
St. David	2.1
St. Johns	2.1
Superior	2.1
Taylor	2.5
Teec Nos Pos	2.1
Tempe	1.0
Thatcher	1.6
Tombstone	2.2
Tonalea	1.9
Tonopah	1.0
Topock	0.7
Tuba City	1.7
Tubac	2.0
Tucson	1.7
Valle	2.6
Wellton	0.5
Whiteriver	3.6
Why	1.2
Wickenburg	1.5
Wide Ruins	2.2
Wikieup	1.5
Wilcox	1.8
Williams	3.3
Winkelman	2.1
Winslow	1.7
Yarnell	3.1
Young	3.4
Yucca	1.2
Yuma	0.4

R-VALUE TO MODULUS CONVERSION CHART

Note: Generally the subgrade design Mr should not exceed 26000 psi

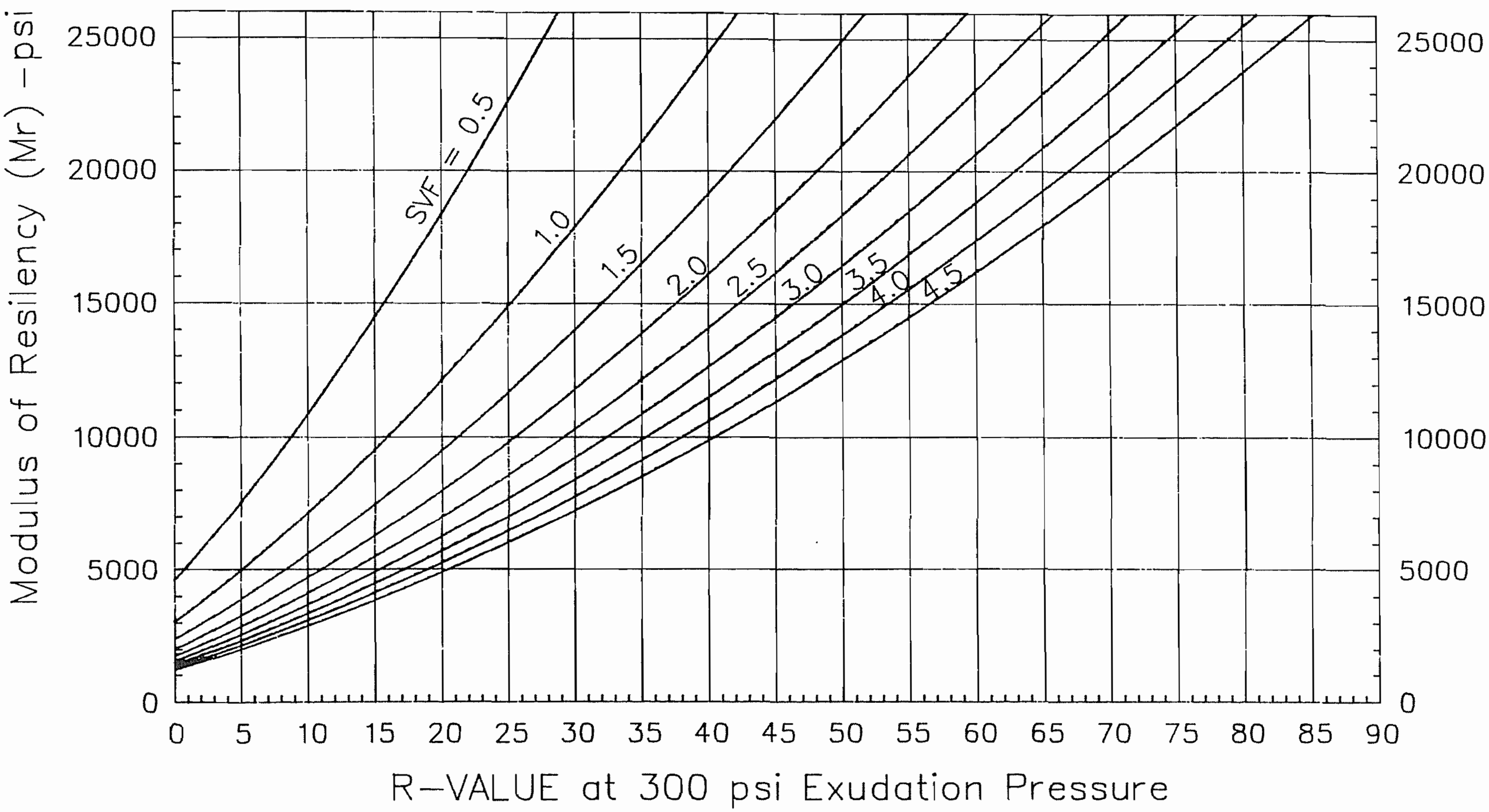


FIGURE 202.02-2

I. Construction Control R-Value Determination

For construction control, the minimum acceptable Rc-value (correlated R-value) should be determined as follows:

For a confidence level of 90%, find the critical value from Table 202.02-5 of the t distribution and for n-1 degrees of freedom.

Multiply the critical t value times the standard deviation from the mean Rc-value determination. Subtract this product from the mean Rc-value. The result will be the minimum Rc-value for construction control purposes.

J. SN - Structural number represents the overall structural capacity needed in the base and surfacing to accommodate the expected traffic loading. It is solved for iteratively to nearest hundredth of a decimal point.

K. a_i - Following the solution of structural number the layer coefficient is determined for each supporting layer. Table 202.02-6 coefficients to be used for a variety of base and surfacing materials.

Circumstances may exist that warrant the use of new materials and/or new variations of materials in such a way that normal coefficients may need to be checked. In addition to this some materials may be substantially altered during construction to the extent that the structural coefficient may need to be changed. If the material in question is statistically controlled with a penalty schedule then coefficient adjustment may not be necessary. With the above conditions in mind the following equations and nomographs should be used to determine the coefficient in question.

Asphaltic Concrete -AC

For AC mixes such as a 1/2" AC, 3/4" AC, recycle, emulsion treated base or any other asphalt material the following equation, which was adapted from the Asphalt Institute along with Figure 202.02-3 can be used to estimate the coefficient.

$$\text{Log}_{10}(E_{AC}) = 6.427936+0.019476*(\text{Pass } 200)-0.03476*(\text{voids}) + 0.070377*(\text{visc @ } 70^{o}\text{F})-0.28646*(\text{\% Asph})^{0.5}$$

TABLE 202.02-5

Critical t Value

Degrees of Freedom (Number of Tests-1)	90% t Value
2	1.886
3	1.638
4	1.533
5	1.476
6	1.440
7	1.415
8	1.397
9	1.383
10	1.372
11	1.363
12	1.356
13	1.350
14	1.345
15	1.341
16	1.337
17	1.333
18	1.330
19	1.328
20	1.325
21	1.323
22	1.321
23	1.319
24	1.318
25	1.316
26	1.315
27	1.314
28	1.313
29	1.311
30	1.310
40	1.303
60	1.296
120	1.289
Over 120	1.282

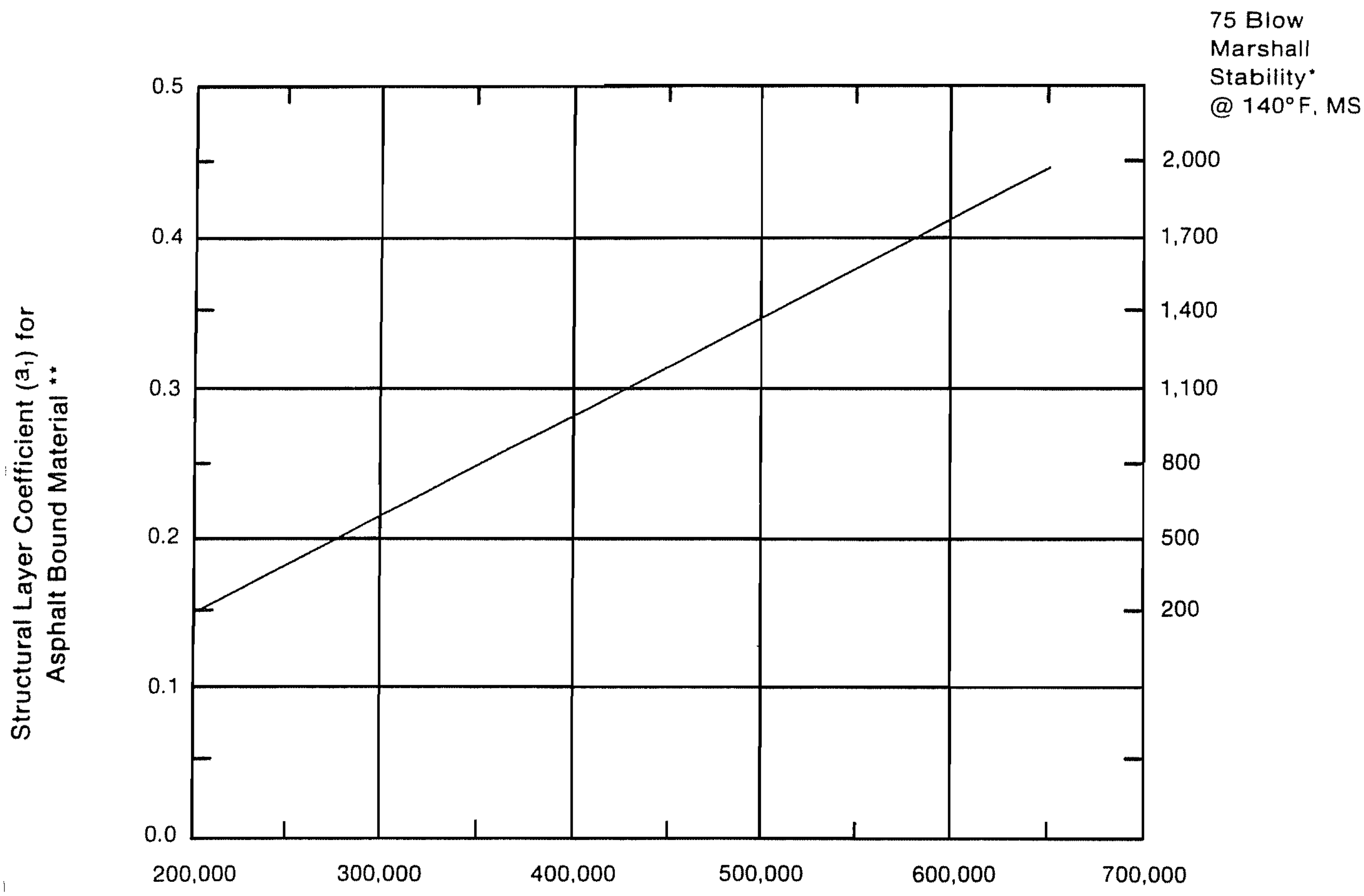
TABLE 202.02-6

SURFACING AND BASE COEFFICIENTS

	Maximum coefficient
Asphaltic Concrete (3/4" or 1/2" Mix; Virgin or Recycled)	.44 - a_1
Cement Treated or Bituminous Treated Base	.28 - a_2
Cement or Lime Treated Subgrade	.23 - a_2
Aggregate Base	.14 - a_2
Aggregate Subbase	.11 - a_3

FIGURE 202.02-3

Chart for estimating structural layer coefficient of asphalt bound material based on elastic modulus or marshall stability



ELASTIC MODULUS, E_{AC} (PSI), OF
ASPHALT BOUND MATERIAL (AT 70°F)

* Flow must be between 8-16

** Coefficient cannot be lower than 0.15 or higher than 0.44.

$a_1 = 0.02 + 6.4 \times 10^{-7}(E_{AC})$

$a_1 = 0.12 + 1.61 \times 10^{-4}(MS)$

Where

E = Elastic Modulus of AC (psi)
For values less than 275,000 psi or 500 marshall stability no coefficient should be assigned. Either re-design mix or consider it a base course. If greater than 650,000 psi or 2,000 marshall stability the coefficient is .44.

Pass 200 = Percent passing the #200 sieve. For purposes of design calculations use the minimum design criteria value.

Voids = Effective voids. For purposes of design calculations use the maximum design criteria value.

Visc.@70°F = Viscosity at 70°F.

$$\text{Visc.@}70^{o}\text{F} = 29508.2 * \left[\frac{\text{Abs. Visc. @ } 140^{o}\text{F}}{303{,}625}\right]^{1.7490}$$

For purposes of design calculations use the smallest allowable absolute viscosity at 140°F for the design asphalt grade.

% Asph. = Percent asphalt by weight. For recycle mixes use only the new asphalt.

Cement Treated Base - CTB

Figure 202.02-4 shows that the CTB coefficient is a function of the seven (7) day unconfined compressive strength. If the compressive strength is less than 200 psi than the material should be considered as aggregate base and the coefficient re-calculated. A coefficient of 0.28 will apply to CTB with 800 psi or more strength.

Bituminous Treated Base - BTB

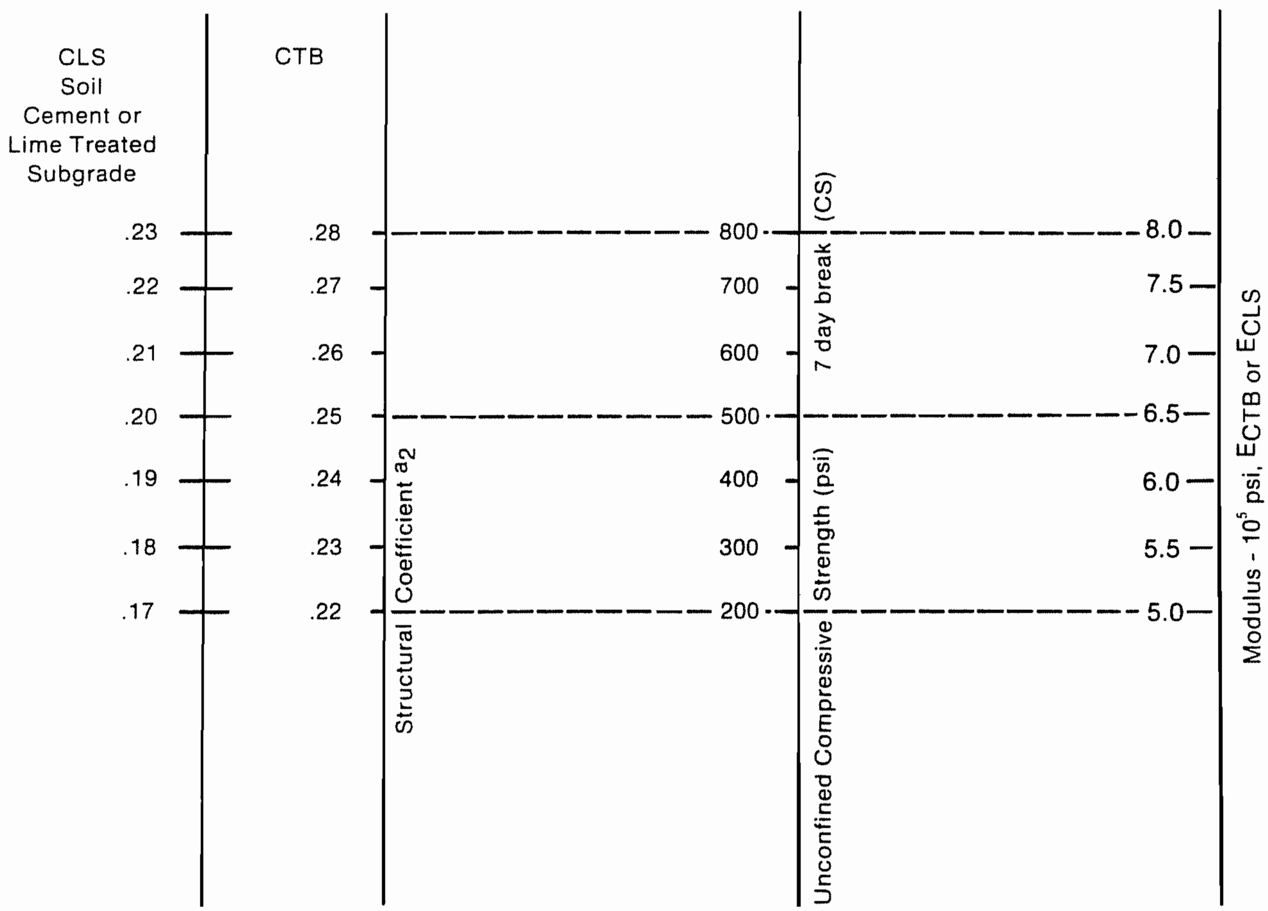
This base will be used primarily as a drainage layer and should be given a coefficient of 0.28.

Soil Cement or Lime Treated Subgrade

Figure 202.02-4 shows that for these materials the coefficient is a function of the seven (7) day unconfined compressive strength. The coefficients are less than CTB because of subgrade variability and construction control. If

FIGURE 202.02-4

Chart for estimating structural layer coefficient of cement treated base (CTB) and stabilized soil subgrade based on unconfined compressive strength or elastic modulus



$a_2 = 0.20 + 0.0001\ (CS_{CTB})$
$a_2 = 0.15 + 0.0001\ (CS_{CLS})$

$a_2 = 0.12 + 2 \times 10^{-7}\ (E_{CTB})$
$a_2 = 0.07 + 2 \times 10^{-7}\ (E_{CLS})$

the compressive strength is less than 200 psi than the material should be considered subgrade. A coefficient of 0.23 will apply to those materials with 800 psi or more strength.

Aggregate Base and Subbase

Figure 202.02-5 shows that the aggregate base and subbase coefficient is a function of R-value, either tested or correlated from PI and -200. For aggregate base material with a 79 R-value or higher the coefficient is 0.14. For a subbase material with a 70 R-value or higher the coefficient is 0.11. For both materials an R-value below 63 is considered subgrade.

L. DRAINAGE COEFFICIENT - M_i

Table 202.02-7 should be used to determine drainage coefficients.

For base materials a drainage coefficient should be applied consistent with the seasonal variation factor (Figure 202.02-1 and Table 202.02-4).

The Seasonal variation factor is used to determine percent of time of saturation exposure.

Definitions of Quality of Drainage are:

Excellent - Specially designed bituminous bound or unbound aggregate porous drainage base layer with at least 2,000 Ft/Day permeability connected to drainage system (Trenches and Pipes).
Good - Specially designed bituminous bound or unbound aggregate porous drainage base layer with at least 2,000 Ft/Day permeability, no drainage system (Trenches and Pipes).
Fair - Typical Aggregate Base.
Poor - Typical Aggregate Subbase.
Very Poor - Subgrade-like material

M. ASPHALT GRADE SELECTION

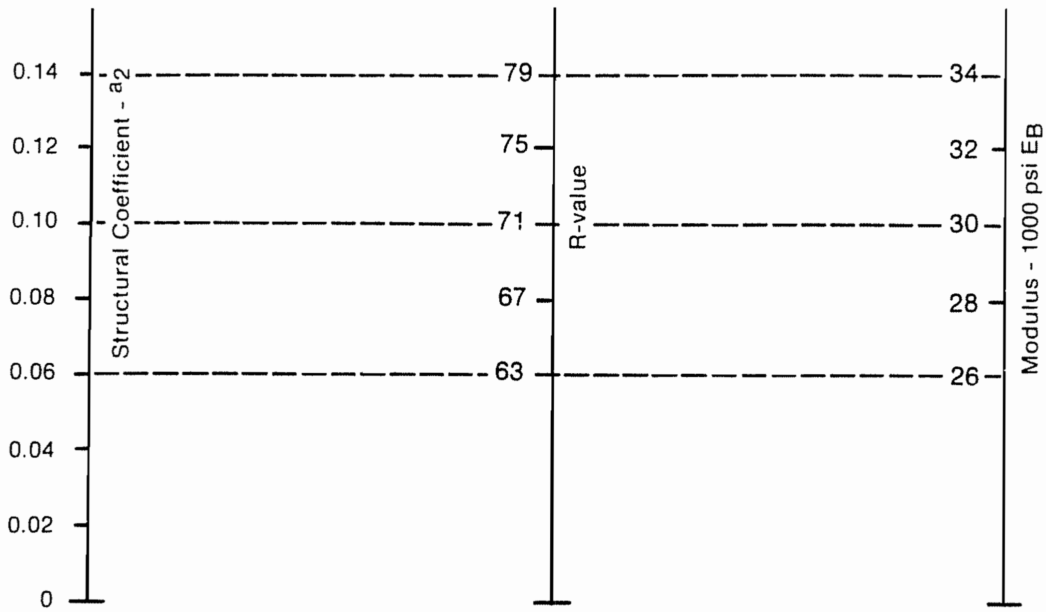
Table 202.02-8 give asphalt grade guides. The grade to be used will be determined by the Bituminous Engineer.

N. MINIMUM INDEX OF RETAINED STRENGTH

Minimum index of retained strength shall be in accordance with Figure 202.02-6 noting that pavement for interstate highways and other high volume roadways will ordinarily require an additional 10%. The retained strength required will be determined by the Bituminous Engineer.

FIGURE 202.02-5

Chart for estimating structural layer coefficient of unbound granular base determined by R-value or elastic modulus.



$a_2 = -0.2550 + 0.0050\ (\text{R-Value})$

$a_2 = -0.20 + 1.00\text{X}10^{-5}(E_B)$

TABLE 202.02-7

ESTIMATE OF DRAINAGE COEFFICIENT (M_i)
AS A FUNCTION OF QUALITY OF DRAINAGE
AND SEASONAL VARIATION FACTOR

QUALITY OF DRAINAGE	SEASONAL VARIATION FACTOR <1.7	1.7 - 2.7	>2.7
EXCELLENT	1.15	1.23	1.32
GOOD	1.07	1.17	1.27
FAIR	1.00	.92	.84
POOR	.93	.83	.74
VERY POOR	.86	.75	.64

TABLE 202.02-8

ASPHALT CEMENT GRADE*
SELECTION CHART

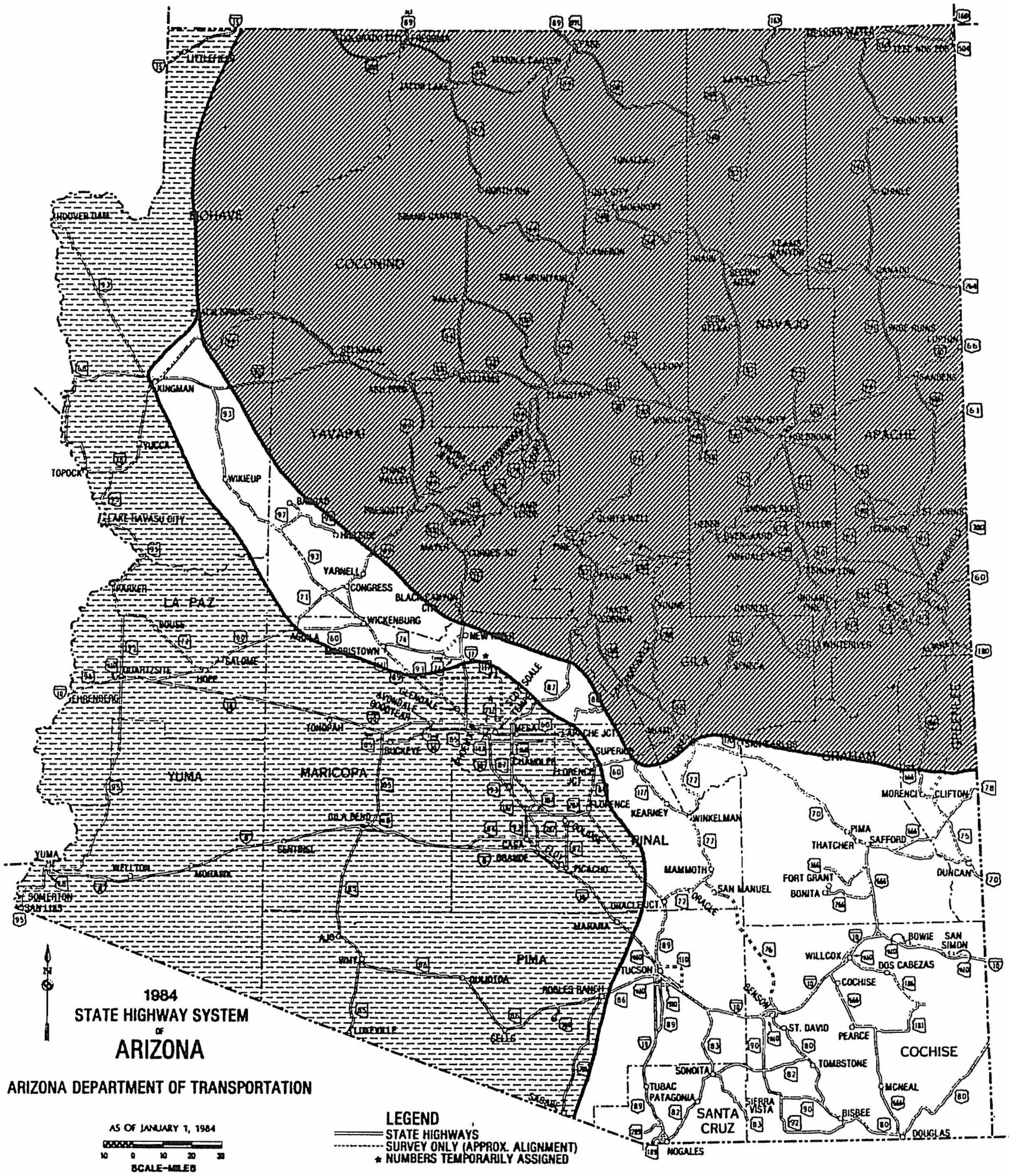
ELEVATION	18 KIP ESAL/YEAR LESS THAN 60,000	MORE THAN 60,000**
0 - 2000′	AC-30	AC-40
2001 - 4000′	AC-30	AC-30
4001 - 6000′	AC-20	AC-30
ABOVE 6000′	AC-20	AC-20

* The grade to be used will be determined by the Bituminous Engineer.

** Includes all Interstate.

FIGURE 202.02-6

INDEX OF RETAINED STRENGTH SELECTION



* An additional 10% is required for Interstate highways.

40% Retention Area *

50% Retention Area *

60% Retention Area *

202.03 - RIGID PAVEMENT DESIGN

The basic design equation for rigid pavements is as follows:

$$\log_{10}(W_{18}) = Z_R \times S_o + 7.35 \times \log_{10}(D + 1) - 0.06 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.5 - 1.5}\right]}{1 + \frac{1.624 \times 10^7}{(D + 1)^{8.46}}}$$

$$+ (4.22 - 0.32 \times p_t) \times \log_{10}\left[\frac{S'_c \times C_d \times (D^{0.75} - 1.132)}{215.63 \times J \left[D^{0.75} - \frac{18.42}{(E_c/k)^{0.25}}\right]}\right]$$

Where

W_{18}	= predicted number of 18-kip equivalent single axle load applications (Rigid), (Appendix A).
Z_R	= standard normal deviate, same as flexible, Table 202.02-1.
S_o	= combined standard error of the traffic prediction and performance prediction, equal to 0.35.
D	= thickness (inches) of pavement slab, cannot be less than nine (9) inches.

S'_C = Average modulus of rupture (psi) for portland cement concrete used on a specific project, fixed at 670 psi. The typical minimum construction control (Sc) value is 500 psi.

C_D = Drainage coefficient same as flexible, Table 202.02-7.

E_C = Modulus of elasticity (psi) for portland cement concrete. It can be estimated from concrete compressive strength (f'_C), by the following formula.

$$E_C = 57000\ (f'_C)^{0.5}$$

For purposes of design f'_C is equal to 5,000 psi and E_C is equal to 4,000,000 psi, based on a minimum f_C equal to 4,000 psi and an average f'_C of 5,000 psi at 28 days as determined by AASHTO T-22.

P_o = Initial design serviceability index, same as Flexible, Table 202.02-2.

P_t = Design terminal serviceability index, same as Flexible, Table 202.02-2.

J = Load transfer coefficient used to adjust for load transfer characteristics of a specific design, Table 202.03-1.

k = Modulus of subgrade reaction is found by first determining the subgrade modulus (see flexible design Section 202.02 (F, G and H). For a full depth design subgrade modulus can be converted to k value with the following formula.

$$k = \frac{M_R}{19.4}$$

Where

M_R = Resilient modulus of subgrade

The design k value is found by correcting for loss of support by using Figure 202.03-1, Figure 202.03-2 and Table 202.03-2.

TABLE 202.03-1

J FACTORS

	Tied Concrete Shoulders: Load Transfer Devices	Tied Concrete Shoulders: No Load Transfer Devices
Plain Jointed, (No Dowels)	N/A	3.9
Jointed Reinforced,(Dowels)	2.8	N/A
CRCP	2.5	N/A

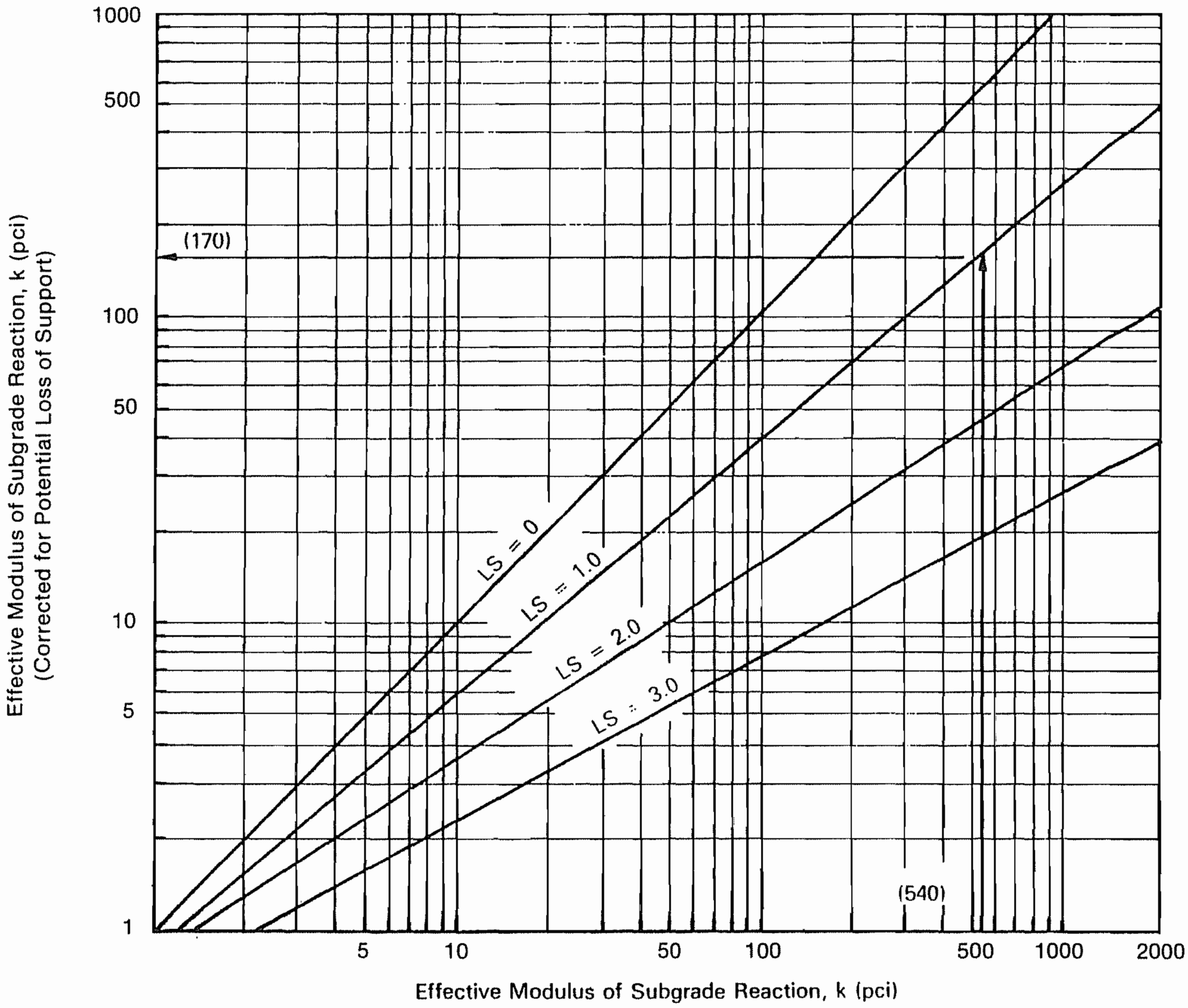
TABLE 202.03-2

LOSS OF SUPPORT

	Modulus	Loss of Support As a Function of Seasonal Variation Factor: 0-1.7	1.8-2.7	2.8+
Asphaltic Concrete	650,000	0	0	0
Lean Concrete Base	650,000	0	0	0
Cement Treated Base	600,000	0	0	0
Cement Treated Subgrade	500,000	0	0.5	1.0
Lime Treated Subgrade	500,000	0	0.5	1.0
Aggregate Base	36,000	0	0.75	1.5
Aggregate Subbase	23,000	0	1.0	2.0
Subgrade		0.5	1.5	2.5

FIGURE 202.03-1

Correction of effective modulus of subgrade reaction for potential loss of subbase support.



$LOG(K)_{CORR} = A_O + A_1 * LOG(K)$

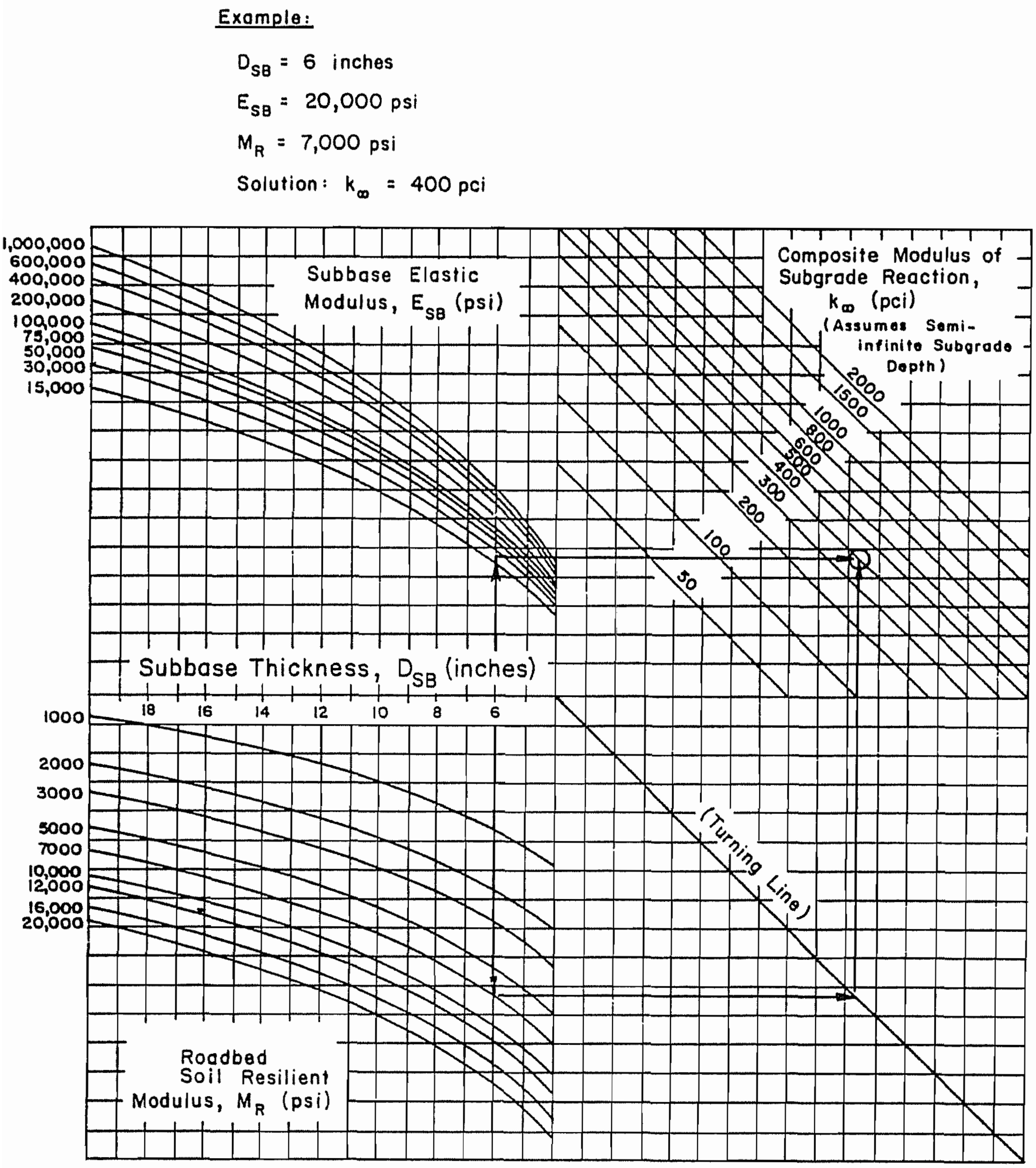
Where: $A_O = -0.0844 * LS^{0.6924}$

$A_1 = 1.0 - 0.1566 * LS$

(NOTE: Logs are in Base 10)

FIGURE 202.03-2

Chart for estimating composite modulus of subgrade reaction, k_∞, assuming a semi-infinite subgrade depth. (For practical purposes, a semi-infinite depth is considered to be greater than 10 feet below the surface of the subgrade.)



For those designs using an unbound or bound base or subbase Table 202.03-2 should be used to determine the modulus, as well as the loss of support. Figure 202.03-2 should then be used to determine the composite K value. The design composite K value is then found by entering Figure 202.03-1 with the appropriate loss of support value.

202.04 - MINIMUM PAVEMENT DESIGN CONTROLS

The AASHTO Road Test structural design equations are based on traffic-induced fatigue failures. There are other criteria which must be considered to avoid impractical designs. Some of these are:

1. Ease of construction
2. Maintenance considerations
3. Current engineering judgement and practice
4. Failure under the action of a few heavy wheel loads

Taking this criteria into account, minimum designs for flexible and rigid pavements were developed.

A. Mainline Highways

The minimum structural number chart should be used to check the adequacy of design. In addition it can be used to estimate a design section when it is not possible to complete the design due to unusual circumstances. For turning bays, bridge replacement, culvert replacement, minor roadway widening or any other highway work involving small areas or small quantities of mainline highway paving, the design structural section should match the existing structural number. If the existing structural number is less than the minimum required then use the larger value. Generally full depth construction is preferable for all small area paving projects, except for widening, which should match the in-place section. For mainline highways the following minimums apply.

Flexible Pavements:

For flexible pavements the minimum is expressed as a structural number which is further qualified by minimum asphaltic concrete thickness. Additionally, on layered sections using aggregate bases, a minimum thickness of 4" shall be used for the base material. Table 202.04-1 shows the minimum requirements for flexible pavements.

TABLE 202.04-1

FLEXIBLE PAVEMENTS MINIMUM STRUCTURAL NUMBERS AND COMPONENT THICKNESS

ROADWAY CLASSIFICATIONS	MINIMUM STRUCTURAL NUMBER			MINIMUM AC THICKNESS
	RURAL ESAL'S		URBAN	
Freeways, all Interstates, non-Interstates with greater than 10,000 ADT	10,000,000< SN	>10,000,000 SN	SN	
Main Roadway	3.00	3.50	3.50	5.0"
Ramps & Crossroads	2.25	2.25	3.50	4.0"
Frontage Road	2.25	2.25	2.72	4.0"
Detours	2.25	2.40	2.40	3.0"
	ESAL's			
Arterials, (ADT 2,001-10,000)	2,500,000< SN	>2,500,000 SN	SN	
Main Roadway	2.50	2.75	2.75	4.0"
Detours	1.75	2.00	2.00	2.5"
	ESAL'S			
Collectors (ADT 500-2,000)	750,000< SN	>750,000 SN		
Main Roadway	2.00	2.25	2.25	3.0"
Detours	1.50	1.75	2.00	2.0"
	ESAL'S			
Local (ADT 500<)	100,000< SN	>100,000 SN		
Main Roadway	1.35	1.75	1.75	2.0"
Detours	0.75	1.50	1.50	*1.5"

* On low volume, short duration detours of 30 days or less, a prime coat may be used in lieu of the minimum AC thickness.

Rigid Pavements:

For rigid pavements the minimum is expressed as a minimum pavement section. The minimum rigid pavement section for all roadways is 9" of Portland Cement Concrete Pavement on 4" of base.

Gravel Roadways:

At least 6" of base should be placed.

B. Non-Mainline Pavements

The following minimum structural number and/or minimum thickness apply to turnouts, driveways, rest areas, parks and any other non-mainline highway pavement. In order to facilitate the design process it is recommended that for rest areas, parks and similar pavements that the traffic loading be estimated to be one percent of the adjoining mainline traffic. Any other design traffic loading estimate will require Materials Section approval.

Flexible Pavements Minimum Structural or Component Thickness

Turnouts and Driveways	Minimum	2" AC on 4" AB
Rest Areas and Parks	Minimum	SN=2.25; 4" AC

202.05 - SELECTION OF OPTIMAL DESIGN

In choosing the optimal design for the pavement structure there are many things to consider.

A. Continuity of Pavement Type

To maintain uniform driving conditions for the motoring public, consideration should be given to continuing the same type of existing pavements, especially if a new project is a relatively short one.

B. Location and Local Conditions

Although there are many pavement designs that will meet the requirements of the design equation, there are situations when local conditions, such as underground utilities close to the surface, poor drainage, flooding, snow pack, etc., where one design might function more efficiently than another. Past experience and judgement should be used in the final selection of the design.

C. Conservation of Natural Resources

A cost comparison computer program determines quantities of aggregates required for each pavement design, and some programs take into consideration the future value of the materials used as well as their salvage value. Conservation of natural resources should be considered in the evaluation of the pavement design, and in areas where aggregate is scarce, it should be given considerable weight.

D. Anticipated Construction Problems

Consideration should be given to the feasibility of the proposed design in regard to standard construction methods.

E. Costs

Comparative costs provided in the pavement design procedure should be given consideration in the selection of the pavement design.

1. Life Cycle Cost

Designers are encouraged to conduct a life cycle cost analysis to determine the most cost effective structural design whenever reasonable to do so. Although structural designs encompass a 20 year period, highway facilities generally are in service much longer and therefore a 35 year analysis period should be used.

In addition to the initial construction cost, several other inputs are needed, including rehabilitation strategies, unit costs, salvage value, user delay cost, maintenance cost, discount rate and traffic control cost. The following describes these inputs in more detail.

a. Construction costs - Cost data is available from ADOT Contracts and Specifications Services in their annual cost summary publication as well as current project bid data. Designers are encouraged to use these references as a guide and to document the sources of all cost estimates. Generally Contracts and Specifications data will be used to referee any disputes about cost estimates.

b. Rehabilitation Strategies - Life cycle performance estimates for new pavements and rehabilitation can be obtained from the pavement management branch of Materials Section. Table

202.05-1 can be used as a guide for most typical pavement designs and rehabilitation strategies. For those design situations not routinely covered further consultation with pavement management is suggested. Any deviations from Table 202.05-1 must be documented and approved by Materials Section.

c. Salvage Value - The following formula will be used to estimate the salvage value as a percentage of the initial cost.

Percent Salvage Value =

$$1 - \frac{(P * (IC + RM - (THN*RV))) + ((1 - P) * (RH - (THR*RV)))}{IC} *100$$

Where:

P = Chance of rebuilding the highway at the end of the analysis period. Historical performance indicates a 0.50 value at 35 years.

IC = Initial cost of the design section in $/sy. Design section includes paving and base layers.

RM = Cost in $/sy to remove paving material during reconstruction.

THN = Thickness of new bound layer in inches.

THR = Thickness of rehabilitated bound layer in inches.

RV = Worth of recycled bound layer in $/sy-in. $0.25/sy-in for AC and zero for all other materials.

RH = Rehabilitation Cost in $/sy.

Salvage values generally fall into the following ranges shown in Table 202.05-2.

d. User delay costs refer to the time that drivers are inconvienced due to reconstruction, rehabilitation or maintenance activities. Research indicates a cost of $0.06 per vehicle mile. By knowing the ADT at time of the activity (day, night and/or weekend), length of project and number of working days the user delay cost can be calculated. User delay costs are not computed for new construction on a new alignment, since other factors such as excavation, drainage etc. will control.

e. The discount rate will be set to four percent.

TABLE 202.05-1

EXPECTED PERFORMANCE LIFE

Flexible Pavements	Years of Service Before Rehabilitation
New Construction 20 Year Design	15
AC Overlays or Recycling 10 Year Design	10

Rigid Pavements	Years of Service Before Rehabilitation
New Construction, 20 year Design	20
Grinding plus Joint Re-sealing	14
Grooving plus Joint Re-sealing	10
AC Overlay of Concrete Full Structural Section (Typically 4" or More)	10
Three Layer System Asphalt Rubber(ACFC, AR, ACFC) Asphalt Rubber AC (Typically 1.5"-2")	5 - 7

TABLE 202.05-2

	Salvage Value as Percentage of Initial Cost
AC pavement with or without base and mill and fill.	31 to 39%
All concrete with or without base and grinding.	-2 to 27%
All concrete with or without base and a three layer overlay.	22 to 39%

f. Maintenance Cost

Maintenance costs were estimated from actual costs compiled from the Pecos maintenance cost file and are shown in Table 202.05-3. Any changes in these costs need to be approved by the Pavement Services Engineer.

F. Summary

Normally the pavement design that satisfies the structural requirements and represents the least cost would be selected. However, as discussed previously, there may be times when the least cost design would not necessarily be the most appropriate design. To the degree possible the designer should take these considerations into account in determining the recommended pavement section. Alternative designs for further review may be appropriate in a situation where no one design seems capable of satisfying all the constraints. For additional information on design consideration the designer should consult the 1986 AASHTO Guide.

TABLE 202.05-3

ESTIMATED MAINTENANCE COSTS

	Cumulative Annual Maintenance Costs	Year Maint. Begins
AC Pavements	$500/lane-mile	1
Concrete without dowels	$100/lane-mile	15
Concrete with dowels	$150/lane-mile	17
Concrete with Reinforcing Steel (CRCP)	$250/lane-mile	19

203.00 DESIGN DOCUMENTATION AND PRESENTATION

This section deals with the documentation and presentation of the information developed during the design process. The method used to present this information is called the Materials Design Package. The Materials Design Package consists of three separate parts, the first is the Pavement Design Summary, the second is the Materials Design Memorandum and the third is the Preliminary Pavement Structure Cost Estimate. A description of each part and the function it serves is presented in the following paragraphs:

203.01 PAVEMENT DESIGN SUMMARY

A pavement design summary is prepared for each project to show the basis for the proposed design. It provides information necessary for review of the design and supports the design recommendations.

The pavement design summary should include the description, location, and reason for a project. Visual observations made by the designer should be listed, especially on rehabilitation projects. Subsoil conditions and geology should be discussed and test results pertinent to the design such as R-values, PI, gradation, moisture, pH and Resistivity, etc. should be mentioned.

For reconstruction or new construction, the selection of the design resilient modulus value should be discussed. Other factors important in the design should be listed including traffic loading and their source, seasonal variation factor, terminal serviceability index, drainage coefficients, and structural coefficients for materials considered. Likewise, for rehabilitation projects similar information, as well as, the deflection analysis should be discussed. If the project is to be divided into sections with different design recommendations, support should be shown for this division, such as, different soil type, different traffic loading, or different existing pavement conditions.

The pavement design summary should list different design alternatives, an economic cost comparison and a discussion explaining the reason for each alternative chosen. Unit costs and total costs should be listed for each design considered.

To be complete, the pavement design summary will give the recommended pavement structure and reasoning for selecting one alternate over the others. A support argument for the design chosen should be made.

203.02 OUTLINE OF PAVEMENT DESIGN SUMMARY

Pavement Design Summary

Project Number

Project Name

I. INTRODUCTION

A. Location (include limits)

B. Description of project

C. Scope of work

II. EXISTING PAVEMENT HISTORY AND VISUAL OBSERVATIONS

A. Existing pavement structure (component thicknesses and dates constructed).

B. Existing pavement condition (list percent cracking and type, ride, surface type and condition, etc.).

C. Observed geologic features, terrain and drainage conditions.

D. Unusual conditions. (Low bridge clearances, cattle guards, railroad crossings, equipment crossings, utilities, curb and gutter, guardrail height, etc.)

III. TEST DATA

A. Pavement Management System Information (skid, ride and cracking values).

B. Dynaflect and falling weight deflectometer information.

C. Soils information (R-values, PI, gradation, pH, resistivity, moistures, frost susceptibility, swell, soil classification and description, etc.).

IV. DESIGN CALCULATIONS AND DISCUSSION

A. New Pavement Design

1. List values used in design equation and explain origin (traffic W_{18}, reliability , effective resilient modulus M_R, Z_R, S_o, PSI, etc.)

2. Discuss design selected and alternates considered as well as life cycle cost if appropriate (list SN required, component layer coefficients, drainage coefficient, seasonal variation factor, costs, special considerations, etc.).

3. Rigid Pavement - if rigid pavement is considered, discuss selection of rigid pavement type, life cycle cost analysis, and values used in rigid design equation.

B. Pavement Rehabilitation Design

1. List basis of design (structural need, deflection design, fatigue related, distress related, etc.).

2. Discuss strategies considered.

V. RECOMMENDATIONS

A. Give pavement section recommended and reasons for selection.

B. Discuss pavement components, special considerations, and pavement surface treatment selection.

VI. SIGNATURE

A. Person submitting design summary shall attach signature.

B. Design summary shall be checked and approved by a Professional Engineer. (Attach Signature).

203.03 MATERIALS DESIGN MEMORANDUM

A Materials Design Memo is prepared for each project to present the outcome of the design process and provide the information and specifications on the recommended pavement structure. The information provided in the Memo is supported by the recommendations made in the Pavement Design Summary and Geotechnical Report.

The Memo provides the recommended pavement structure for each design section including the limits for each design section and the component type and thickness in inches for each section. Additionally the surface course or treatment shall be listed and on new or widened pavements the total thickness should be included.

In addition to providing the pavement structure for each design section, the Memo provides the procedures and specifications for each pavement component or process, which may include the following: existing pavement removal, subgrade preparation, subgrade acceptance, subbases, bases, surface treatments, pavements, etc. If the item is covered by the standard specifications then reference to the standard specification is all that is needed.

Also included in the Memo is information provided by the Geotechnical Report including:

Materials Sources and haul distances, Earthwork Factors and Slopes, Ground Compaction Requirements, Water Requirements and Sources, Pipe Life Information, Special Conditions, etc.

Much of the memo is made up of Design Memo Standard Items and these should be used whenever applicable. The format of the following example should be adhered to as closely as practical.

203.04 OUTLINE AND EXAMPLE OF MATERIALS DESIGN MEMORANDUM

The Materials Design Memo shall contain the memorandum number, the project reference and the materials design information.

A. Memorandum Number

Memos are numbered consecutively beginning with the number one with a prefix of the last two digits of the year in which it is written, e.g., 88-1. Subsequent memos for the same project are given consecutive suffix numbers beginning with the number one, e.g., 88-1-1, when minor changes are made. If the original memo becomes very old or completely obsolete, a new number is assigned.

B. Project Reference

Each Memo refers to a specific project and to identify the project the following information is listed: the name of the highway and route number, the location of the project on that highway (project name), the construction number, the preliminary engineering number, the type of construction, and the beginning and ending milepost and corresponding stationing. For example:

PROJECT

MEMORANDUM #88-5

CORDES JCT.-PRESCOTT HWY (SR 69)
PRESCOTT VALLEY-PRESCOTT, UNIT II
F-029-1 (6) C
F-029-1-406 PE
WIDENING, OVERLAY & NEW CONSTRUCTION
MP 289.62 (STA. 4668+00) TO MP 294.68 (STA 4930+00)

MEMORANDUM TYPE:
INITIAL FOR REVIEW

C. Design Information

The design information is presented in sections with each section broken into items, as follows:

SECTION I - PAVEMENT STRUCTURE

ITEM 1 - STRUCTURAL THICKNESS (In Inches)

The structural thickness includes the termini of each design section, the type and thickness of each pavement component, and the total thickness, all expressed in inches (The total thickness need not be included on rehabilitation projects). For example:

Station	AB	AC(3/4)	ACFC	Total Thickness
4668+00 to 4789+00 (Widening)	15	7 1/2*	1/2	23
4789+00 to 4837+70 (Widening)	6	7 1/2*	1/2	14
4837+70 to 4854+30 (Widening)	18	7 1/2*	1/2	26
4854+30 to 4910+55 (New Cst)	18	7 1/2	1/2	26
4910+55 to 4930+00 (Widening)	18	7 1/2*	1/2	26

*Includes a 2 1/2 inch overlay on existing SR 69.

On overlay projects where the existing roadway is out of section or has a rough ride an item designating additional quantities for leveling should be included.

ITEM 2 - ADDITIONAL QUANTITIES FOR LEVELING

An additional 1,500 tons of asphaltic concrete (3/4) shall be estimated for leveling purposes. 500 Tons of the material shall be utilized for miscellaneous paving and spot patching or blade laid leveling of the roadway prior to the placement of overlay. 1,000 Tons of the material shall be added to the overlay for leveling purposes between Sta. 4668+00 to Sta. 4854+30.

Typically, the second page of the Design Memorandum is a vicinity map showing the project location and the location of any materials pits involved. (Figure 203.04-1).

Following the vicinity map is the Typical Section Sheet or sheets. (Figure 203.04-2). The typical section shows a graphic illustration of the roadway typical sections and the pavement structure. The pavement structure shows the type, thickness, and placement of each pavement component and lift. Figure 203.04-3 shows the recommended symbols for each pavement component and treatment to be used on the typical sections.

SECTION II - SUBGRADE, SUBBASES AND BASES

This section sets forth the recommended specifications for subgrade, subbases and bases. These items should be listed in the order of their placement during construction and may include, but are not limited to the following:

Subgrade Construction Control
Cement Treated Subgrade
Aggregate Subbases
Cement Treated Base
Lean Concrete Base
Aggregate Bases

ITEM 1 - SUBGRADE CONSTRUCTION CONTROL

This item is to be included on projects that involve new subgrade construction. The subgrade acceptance chart (Figure 203.04-4) shall be included in the Memo following the typical sections or an equivalent equation shall be included when there is no designated borrow source.

The attached subgrade acceptance chart should be used during construction for determining whether subgrade materials are suitable as outlined in Section 203.06 of the ADOT Construction Manual.

FIGURE 203.04-1

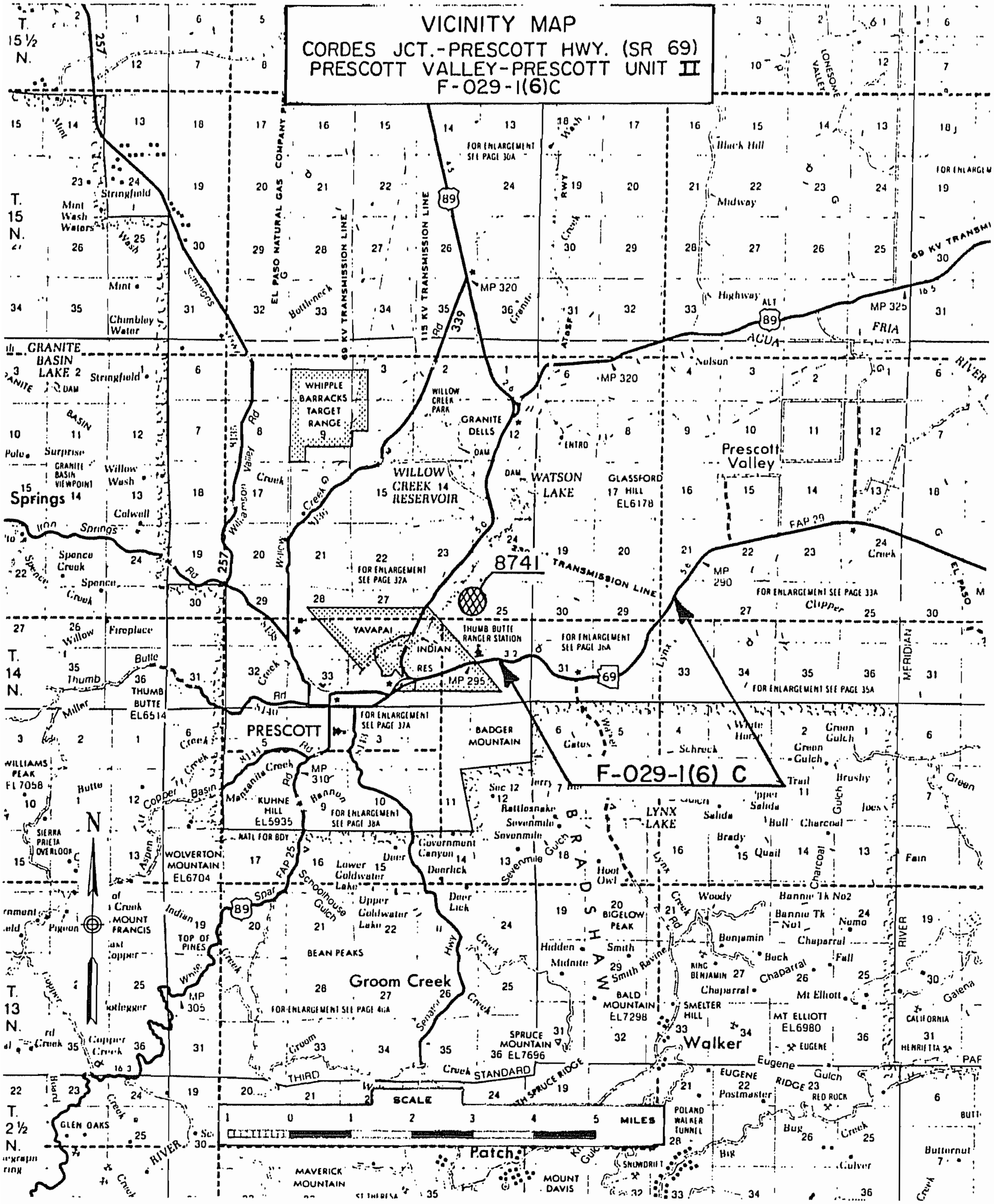
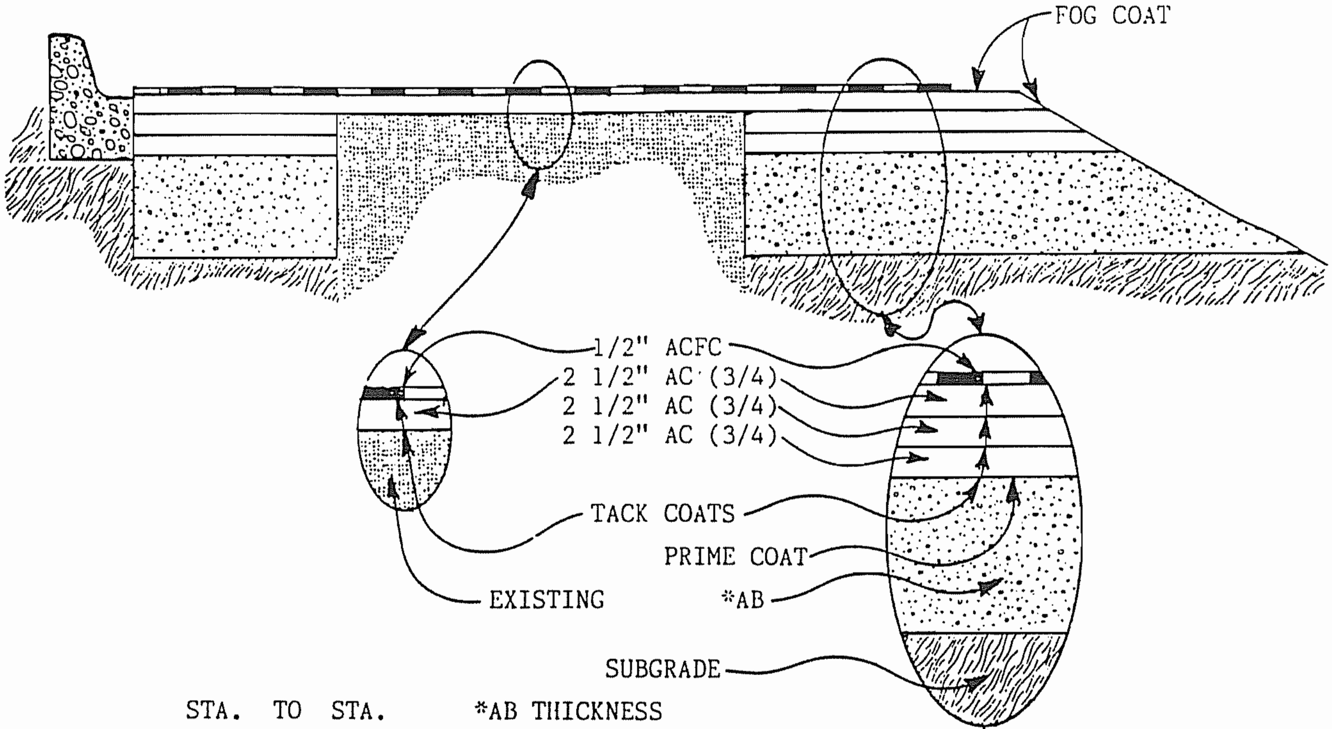


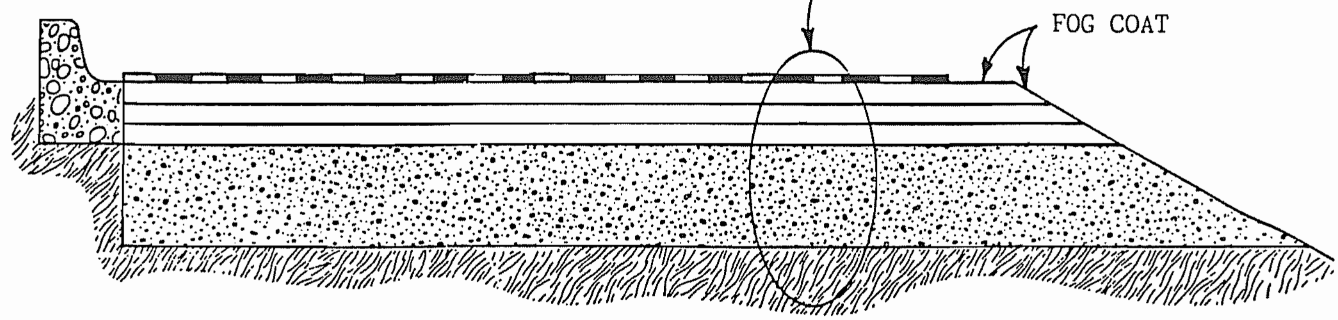
FIGURE 203.04-2

TYPICAL SECTIONS

F-029-1(6) C
PRESCOTT VALLEY - PRESCOTT, UNIT II



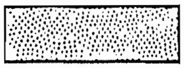
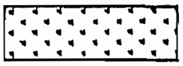
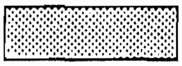
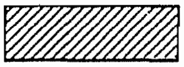
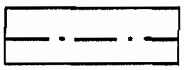
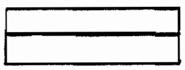
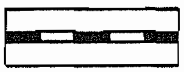
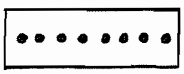
STA. TO STA.	*AB THICKNESS
4668+00 - 4789+00	15"
4789+00 - 4837+70	6"
4837+70 - 4854+30	18"
4910+55 - 4930+00	18"



STA. TO STA.	*AB THICKNESS
4854+30 - 4910+55	18"

FIGURE 203.04-3

TYPICAL SECTION SYMBOLS

LEGEND	DESCRIPTION
	SUBGRADE
	EXISTING ASPHALTIC CONCRETE / BASE
	CEMENT TREATED SUBGRADE / LIME TREATED SUBGRADE
	AGGREGATE SUBBASE
	AGGREGATE BASE
	CEMENT TREATED BASE / LEAN CONCRETE BASE
	ASPHALT TREATED BASE
	DRAINAGE LAYER / ARRESTER BED AGGREGATE
	ASPHALTIC CONCRETE
	RECYCLE PAVEMENT
	REMOVE AC & REPLACE W/NEW AC
	PORTLAND CEMENT CONCRETE PAVEMENT
	MEMBRANES / GEOTEXTILES / GEOGRIDS
	PRIME COAT
	TACK COAT / FOG COAT
	CHIP SEAL COAT
	ASPHALT CONCRETE FRICTION COURSE
	GRIND OR GROOVE PCCP / RECYCLE EXISTING BITUMINOUS SURFACE
	BORROW

ITEM 2 - AGGREGATE BASE

Aggregate base should be Class 3, and shall be as specified in Section 303 of the Standard Specifications. The grading shall be as follows:

Sieve Size	% Passing
1"	100
3/4"	80 - 100
3/8"	55 - 75
#8	30 - 45
#200	0 - 8

The plasticity index shall not exceed 3.

For estimating purposes the haul distance is approximately 6 miles.

SECTION III - SURFACE TREATMENTS AND PAVEMENTS

This section sets forth the recommended specifications for the various pavement components. Those components should be listed in the order of their placement during construction and may include, but are not limited to, the following:

Prime Coat
Tack Coat
Asphalt Rubber Stress Absorbing Membrane
Asphaltic Concrete
Asphaltic Concrete Finishing Course
Portland Cement Concrete Pavement
Chip Seal Coat
Fog Coat
Blotter Material

The Standard Specifications cover most of the items; however, where there is a deviation from, or not covered in the Standards the specification should be detailed in the item.

ITEM 1 - PRIME COAT

The prime coat shall be as specified in Section 404 of the Standard Specifications.

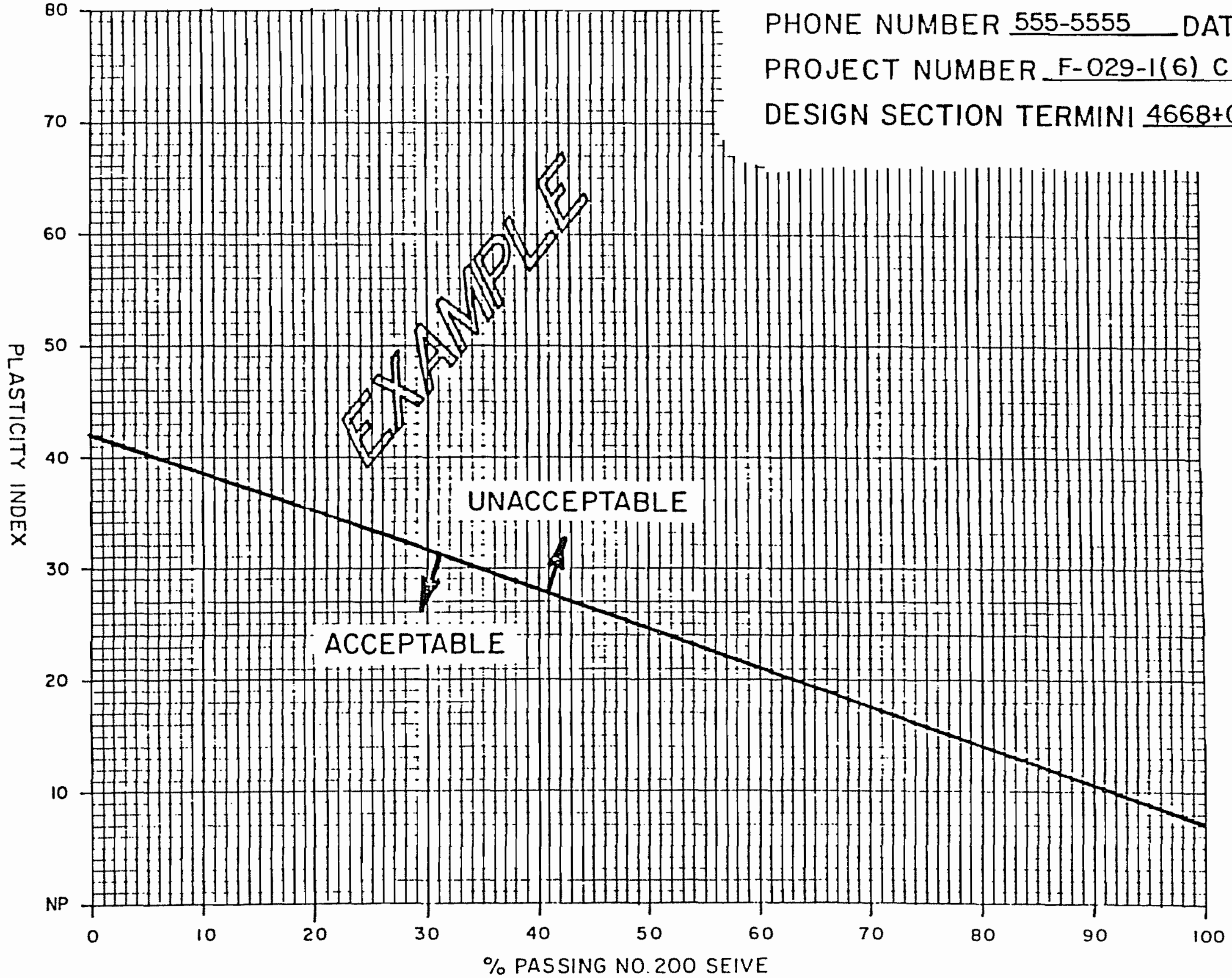
The prime coat should be applied to the surface of the aggregate base at an approximate rate of 0.5 gallon per square yard.

DESIGNER X. JONES

PHONE NUMBER 555-5555 DATE 8-19-87

PROJECT NUMBER F-029-1(6) C

DESIGN SECTION TERMINI 4668+00 TO 4930+00



ARIZONA DEPARTMENT OF TRANSPORTATION

MATERIALS SECTION SUBGRADE ACCEPTANCE CHART

FIGURE 203.04-4

ITEM 2 - TACK COAT

A tack coat shall be applied as necessary to provide proper bonding prior to the placement of each lift of AC or ACFC over an underlying bituminous surface. The tack coat shall be as specified in Section 404 of the Standard Specifications.

ITEM 3 - ASPHALTIC CONCRETE (3/4) (END PRODUCT)

The asphaltic concrete shall be as specified in Section 416 of the Standard Specifications.

For estimating purposes the unit weight of the bituminous mix is 150 pounds per cubic foot, the asphalt is 4.7%, and the haul distance is 6 miles.

The asphalt type shall be AC-20.

The minimum index of retained strength shall be 60%.

The effective voids shall be 6.0%±0.2%.

The combined bulk specific gravity range shall be 2.35 to 2.85.

The combined water absorption range shall be 0 to 2.5.

ITEM 4 - ASPHALTIC CONCRETE FRICTION COURSE

The asphaltic concrete friction course shall be as specified in Section 407 of the Standard Specifications.

Quantities are estimated on a spread rate of 59 lbs. per square yard which includes 25% for leveling to provide a minimum 1/2 inch thickness, however, the exact spread rate shall be determined by the Engineer.

The asphalt shall be 5.5% of type AC-20 and the estimated haul distance for the ACFC is 6 miles.

It has been determined that the average elevation of the roadway for this project is 5400 feet.

One percent (by weight of the asphalt) of an approved asphalt cement liquid additive shall be added to the asphalt.

ITEM 5 - FOG COAT

The fog coat shall be as specified in Section 404 of the Standard Specifications except for the following:

The bituminous material shall be ERA-25, diluted with 1 part water to 1 part ERA-25.

The bituminous material shall be applied at a rate of 0.10 gallons per square yard.

When a fog coat is specified for new asphaltic concrete, it shall be applied as soon as practicable after placing the asphaltic concrete.

ITEM 6 - BLOTTER MATERIAL

The blotter material shall be as specified in Section 404 of the Standard Specifications.

An application of blotter material may be required following the placement of a fog coat and prior to opening the roadway to traffic. The Engineer may direct that after the bituminous material has been allowed to adequately penetrate, blotter material be applied in one or more applications for a total application of 2 pounds per square yard.

The estimated haul distance is approximately 6 miles.

SECTION IV - MATERIAL SOURCES - GEOTECHNICAL ANALYSIS

The materials sources section designates sources of borrow and special backfill. Each source is listed separately showing the data pertaining to that source. Material sources for mineral aggregate and aggregate base are not usually designated since commercial sources are usually available. These would be described as non-designated sources.

Geotechnical analysis includes the pertinent items that were developed during the geotechnical investigation and are usually obtained from the geotechnical report. The geotechnical analysis items may include but are not limited to the following:

Ground Compaction
Earthwork Factors (Shrink/Swell)
Slope Factors
Water Requirements and Sources
Pipe Life Information (pH and Resistivity
Special Conditions

ITEM 1 - NONDESIGNATED SOURCES

No State designated aggregate source is set up for this project. Materials sources shall be as specified in Section 1001 of the Standard Specifications.

ITEM 2 - BORROW

DATE OF REPORT: January 1986

PIT SERIAL NUMBER: #8741

MATERIAL DESIGNATION: BORROW

LOCATION AND DESCRIPTION:

This source is located approximately 2600 feet southeast of Station 1595 (MP 314.5) on US 89 adjacent to a City of Prescott landfill site. The materials available at this source consists of cemented sands, gravels, and cobbles with traces of clay. The materials will require ripping in most areas of the pit to develop the borrow quantities.

EXTRACTION OF PIT MATERIAL:

Light clearing of grass and small brush will be required on portions of the pit area. Stripping will not be required. The estimated quantity of borrow material available for this project at this source is in excess of 60,000 cubic yards after an excavation factor has been applied. The materials shall be removed to the lines and grades obtained from the City of Prescott.

INVESTIGATION:

The investigation of this source consisted of the excavation of 12 test holes in May, 1985. The test holes were dug to depths of from 2.5 to 47 (face sample) feet. No water was encountered at the time the test holes were dug.

INFORMATION AVAILABLE TO BIDDERS:

The following information is available at the office of the Materials Section, 206 South 17th Avenue, Phoenix, Arizona 85007:

1. Drillers logs and laboratory test results on the test holes dug in May, 1985.

2. Aerial photographs and geologic maps of the general pit area.

HAUL ROAD AND HAUL DISTANCE:

Moderate to heavy blade work will be required to construct a haul road from the pit area to connect with an existing haul road utilized by the City of Prescott, a distance of approximately 1000 feet. The haul distance to the project via Sundog Ranch Road, Slaughter House Road, and US 89 to the west end of the proposed project is estimated at 2 miles. Legal loads will be required.

MISCELLANEOUS INFORMATION:

The usable materials will have a compacted weight of approximately 125 pounds per cubic foot and an even excavation factor.

ITEM 3 - GROUND COMPACTION

The following ground compaction factors shall be compensated for on embankment sections outside the existing roadway prism.

Station	Ground Compaction (ft.)
4668 to 4724	0.20
4724 to 4770	0.15
4770 to 4835	0.25
4835 to 4854	0.20
4854 to 4882	0.10
4882 to 4905	0.20
4905 to 4930	0.30

ITEM 4 - EARTHWORK FACTORS AND SLOPES

The following excavation factors and slopes shall be used for project development.

Station	Excavation Factors	Slopes
4668 to 4690	15% Shrink	C-2.20
4690 to 4719	10% Shrink	C-2.20
4719 to 4731	15% Shrink	C-2.20
4731 to 4742	Swell 5%	C-2.20 Lt.,3/4:1 Rt.
4742 to 4756	10% Shrink	C-2.20
4756 to 4776	Even	C-2.20
4776 to 4790	5% Shrink Lt.,Swell 5% Rt.	Daylight Lt.,1/2:1 Rt.
4790 to 4805	10% Shrink	C-2.20
4805 to 4814	Swell 5%	1:1
4814 to 4819	Even Lt.,Swell 10% Rt.	1:1 Lt.,3/4:1 Rt.
4819 to 4825	Even Lt.,Swell 5% Rt.	1:1 Lt.,Daylight Rt.
4825 to 4837	Even	1:1 Lt.,3/4:1 Rt.
4837 to 4845	Even Lt.,Swell 5% Rt.	1:1 Lt.,3/4:1 Rt.

Station	Excavation Factors	Slopes
4845 to 4856	Even	3/4:1
4869 to 4895	Even	C-2.20
4895 to 4908	Even	1:1
4908 to 4918	Swell 5%	1:1
4918 to 4930	15% Shrink	C-2.20

ITEM 5 - WATER

Approximately 65 gallons of water per cubic yard, should be estimated for compaction of base materials. Water can most likely be obtained from the City of Prescott, an approximate haul distance of 2 miles.

ITEM 6 - pH AND RESISTIVITY

If a corrugated metal pipe culvert is to be used, then the type of metal pipe and coating should be determined by the pH and resistivity of in-place materials listed below.

This information should be used in conjunction with Figure 203.04-5.

In-Place Materials:

Station (Location)	pH	Resistivity(ohm-cm)
4683+16 (60′ Rt.)	7.8	1200
4689+80 (60′ Rt.)	8.0	2000
4703+90 (50′ Rt.)	8.0	2600
4719+10 (50′ Rt.)	8.0	5900
4746+35 (40′ Rt.)	7.8	2700
4762+80 (45′ Rt.)	7.9	2000
4772+45 (40′ Rt.)	7.9	2300
4789+77 (45′ Rt.)	6.9	3900
4792+90 (89′ Rt.)	6.9	3900
4803+83 (45′ Rt.)	6.9	4300
4813+53 (40′ Lt.)	6.9	4400
4823+80 (45′ Lt.)	7.4	3400
4829+18 (40′ Lt.)	7.9	1900
4865+50	7.9	700
4873+80 (50′ Rt.)	6.8	1300
4896+75	8.0	1100
4903+00	7.6	1500

ALLOWABLE TYPES OF CULVERT PIPE FOR ph RANGE 5.0 to 9.0[1]

Resistivity (ohm-cm)	Allowable Pipe
2000 or Greater	A[2] - B - C - D
500 - 1999	C - D
Less than 500	D

TYPES OF CULVERT PIPE

A) Galvanized Coated Steel
AASHTO M-36

B) Aluminum Coated Steel
AASHTO M-36

C) Aluminum Alloy
AASHTO M-196

D) Bituminous Coated
AASHTO M-190

Notes: (1) If ph is outside the range of 5.0 to 9.0, a special study of the situation should be made.

(2) Not allowed when ph is less than 6.0

REVISED 2/83

FIGURE 203.04-5

ITEM 7 - ROADWAY EXCAVATION

Any subgrade material encountered at the following locations which does not meet the subgrade controls set for these areas shall be removed to a depth of 3 feet below finished subgrade elevation and replaced with suitable material. The material removed from these areas may be used in the lower reaches of the larger fills (3 feet below finished subgrade elevation).

Right	Station 4810+80 to 4811+80
Right and Left	Station 4858+00 to 4866+00

Any additional areas encountered, which in the opinion of the Engineer may cause an unstable condition shall also be removed to a depth of 3 feet below finished subgrade elevation and replaced with suitable material.

The estimated quantity for subgrade removal and replacement is 7500 cubic yards.

SECTION V - MISCELLANEOUS

Miscellaneous Section includes items that would not be covered under the other sections.

ITEM 1 - TURNOUT CONSTRUCTION

Minor turnouts and driveways designated to be surfaced as shown in the project plans shall be constructed of 2 1/2 inches AC (3/4) placed over 4 inches AB Class 3. Major crossroads shall have the same pavement section as the main roadway.

ITEM 2 - TEMPORARY CONNECTIONS AND DETOURS

The temporary surfacing should consist of 2 1/2 inches of AC (3/4) placed over 5 inches of Aggregate Base (Class 3).

At a time specified by the Engineer, the bituminous surfacing and the base material shall be broken up and picked up separately and stockpiled individually at sites designated by the Engineer. The remaining detour roadways shall be removed, and the natural subgrade shall be restored as nearly as practicable to the condition existing prior to the construction of the detour.

No measurement for payment will be made for the work of removing the detours and stockpiling the material, the cost being considered as included in the cost of the contract items.

The Materials Design Memorandum shall be signed by a Professional Engineer.

Submitted by ________________________________P.E.

Approved by ________________________________P.E.

203.05 PRELIMINARY PAVEMENT STRUCTURE COST ESTIMATE

A pavement cost estimate for each project is developed from the recommended pavement structure. This cost estimate should not be confused with the economic cost comparison of alternate designs used in the design summary, for this estimate represents the anticipated bid prices of the recommended pavement section. The cost estimate gives only the costs for the pavement structure and related items, and does not represent the total costs for a project. The Preliminary Pavement Structure Cost Estimate is used for comparison purposes to ensure reasonable compliance with the programmed amount for pavements on each project. An example of a Preliminary Pavement Structure Cost Estimate and the recommended format are shown in Figure 203.05-1.

204.00 DESIGN REVIEW AND DISTRIBUTION

204.01 REVIEW AND APPROVAL OF MATERIALS DESIGN MEMORANDUM BY MATERIALS SECTION

After the Pavement Design Engineer has completed a Materials Design Memorandum and it has been typed in draft form, it is checked by other Services within Materials Section to assure that items regarding their function are correct. This may include; review by the Geotechnical Engineer for update of pit information, earthwork items, slope ratios, and other related items, review by the Testing Services Engineer for asphaltic concrete and other materials specifications; review by the Pavement Services Engineer, and finally review by the Assistant State Engineer, Materials Section. Any changes that need to be made are noted and made. A vicinity map showing the location of the project and designated pits is included with the memo along with a typical section of the proposed design. Also included is a subgrade acceptance chart when appropriate.

PRELIMINARY PAVEMENT STRUCTURE COST ESTIMATE <——— Heading

F-029-1(6) C <——— Construction #

Prescott Valley - Prescott, Unit II <——— Project Name

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT
Aggregate Base, Class 3	Cu. Yd.	214,000	$ 9.50	$ 2,033,000
Asphalt Cement (AC-30) (3/4" Mix)	Ton	3,422	185.00	633,070
Asphalt Cement (AC-20) (ACFC)	Ton	293	200.00	58,600
Bituminous Tack Coat	Ton	155	120.00	18,600
Apply Bituminous Tack Coat	Hour	480	110.00	52,800
Fog Coat	Ton	10	200.00	2,000
Provisional Seal Coat	Ton	120	175.00	21,000
Apply Provisional Seal Coat	Hour	40	100.00	4,000
Blotter Material	Ton	23	25.00	575
Asphaltic Concrete (3/4" Mix)	Ton	72,800	18.00	1,310,400
Mineral Admixture (3/4" Mix)	Ton	1,456	90.00	131,040
Asphaltic Concrete Friction Course	Ton	5,318	20.00	106,360
			TOTAL	$ 4,371,445

Preliminary Cost Estimate:
Subject to design changes,
additions, alterations,
and corrections.

Pavement Costs = $ 4,371,445
Programmed Amount for Pavement = Unknown
Total Programmed Amount = $ 9,100,000

FIGURE 203.05-1

204.02 DISTRIBUTION OF MATERIALS DESIGN MEMORANDUM

The Materials Preliminary Design Report (MPDR) and Initial Design Memo are prepared and distributed for information, review and comment. The MPDR is typically a one page overview of the most likely design section and geotechnical factors including ground compaction, slopes and shrink and swell when applicable. This report is issued as soon as sufficient information (historical or laboratory) is available to make a reasonable estimate. The purpose of the report is to provide adequate information to prepare the initial plans and earthwork calculations. The initial memo is circulated internally within Materials Section for comments. Following this it is distributed for review and comments to other ADOT services and sections and district offices, as well as, the Federal Highway Administration when applicable. Reviewers are asked to make comments within ten working days after receipt.

205.00 FINALIZATION OF DESIGN, FINAL DESIGN MEMO

If after the review period some comments have not been returned the designer should call to ascertain any comments. Giving each comment appropriate consideration, the Final Memo should be prepared as soon as practical (generally no more than two weeks after the review period ends). The Final Memo should be circulated for review and comments within materials, typed, signed and distributed typically within a subsequent two week period to other ADOT Services, Sections, District Offices and the Federal Highway Administration when applicable.

Since the Final Memo is distributed typically at least three months before the bid date, the designer may have to issue an addendum to Contracts and Specifications Services to update any last minute specification changes.

205.01 SOIL PROFILE

Under the direction of the Geotechnical Site Supervisor of Geotechnical Services, a soil profile should be prepared. This soil profile should show the location of the test holes, the depth of the test holes, the plasticity index, sieve analysis and R-value of the material in the various strata and the general description of the material.

The soil profile is prepared by placing the pertinent data on a copy of the profile as prepared for the final plans of the project. This soil profile, together with other materials information is available for examination by prospective bidders at the offices of the Assistant State Engineer, Materials Section.

A. TEST HOLES

The test holes should be drawn on the profile at the locations and elevations indicted on the field working profile and test hole log which has been prepared by the field crew. Care should be taken to indicate the hole at the proper elevations and offset from the centerline.

B. PLASTICITY INDEX, SIEVE ANALYSIS DATA AND "R"-VALUE

The plasticity index, sieve analysis data and "R"-value data of the various strata of materials in each test hole should be shown on the soil profile. This may be accomplished by pasting a copy of the subgrade test data from the computer print-out as close to the test hole as possible with an arrow pointing to the hole or portion of the hole to which the data applies. If there is no computer printout available, the data should be printed on the profile.

C. MATERIALS DESCRIPTION

A general description of the type of material found in each stratum of each test hole should be shown at the proper location on the soil profile. The information for this description may be found in the log of the subgrade test holes prepared by the Field Crew Chief.

205.02 CHECKING OF PLANS AND SPECIAL PROVISIONS

As soon as they are available prior to bid call, the plans and special provisions should be checked by the Materials Design Engineer who prepared the materials design recommendations to ascertain if they are all in agreement. Any deviations from the intent of the materials design as stated in the materials memo should be noted on the file copies of both the Assistant State Engineer and Materials Pavement Engineer. If the deviation is sufficient to warrant a change, the proper section should be notified of the required change.

205.03 ASSEMBLING MATERIALS DATA FOR FINAL PLANS AND FOR DISTRICT INFORMATION

When a construction project is advertised for bids, a notice from the Contracts and Specifications Services is forwarded to the Materials Section showing the project number, the termini of the project, and the serial numbers of the pits to be used on the project.

On all projects involving Federal funds, one complete set of roadway plans should also be requested in the "Special Instructions" space and this set of plans should be delivered to the Supervisor of the Final Records and Samples, for use by his crew.

206.00 CONSTRUCTION PROBLEMS

When a project has gone to contract the Materials Design Engineer shall be prepared to answer questions pertaining to the materials design or materials field problems which may be encountered during construction. The materials questions and field problems need to be handled expeditiously in order to prevent construction delays.

One of the common materials problems during construction occurs at the time the subgrade is being tested for acceptance. On projects involving subgrade preparation the materials design memo contains a subgrade acceptance chart. (Figure 203.04-4) The chart is used by field construction personnel for determining the design acceptability of the subgrade soils. When a subgrade sample falls within the unacceptable region the field personnel will notify the materials designer of the test results. The designer compares this information with the results of the original design. The construction personnel continue sampling the unacceptable material in increments of 100 feet until the limits of the failing material has been determined. Using this information the designer determines the best method of dealing with the unacceptable subgrade material. Some of the methods used to treat this material are as follows.

1. Overexcavate and replace with acceptable material.

2. Cement or lime stabilization.

3. Use geosynthetics (fabrics, grids, membranes, etc.).

4. Increase the pavement structural number to compensate for weaker soils.

In addition to unacceptable subgrade material, other construction problems relating to materials may occur, a few of which are as follows.

1. Subgrade moisture problems.

2. Slope problems.

3. Drainage or erosion problems.

4. Out of specification material.

As with all questions relating to field problems, these items should be analyzed and expedited by the Design Engineer as judiciously as possible.